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SCIOTO RIVER STUDIES LOW FLOW PERIOD, SEPTEMBER 1953-JANUARY 1954

ENVIRONMENTAL HEALTH CENTER
CINCINNATI, OHIO

PREPARED FOR
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REPORT

ON

SCIOTO RIVER STUDIES

LOW FLOW PERIOD

September, 1953 - January, 1954

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Studies were made in relation to the use of the Scotia River as a source of raw water supply for the Atomic Energy Commission's Portsmouth Plant. Results of these studies, conducted in the fall of 1953 during a period of low flow in the Sciota River are reported. Data is presented regarding significant sources of pollution and existing water supplies in the Sciota River basin.

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U. S. DEPARTMENT OF
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The Ohic and Tennessee Drainage Basins Office, U. S. Public Health Service, supplied data and personnel to assist in performing the field studies.

The U. S. Geological Survey (Ohio District) and the U. S. Weather Bureau (Columbus and Cincinnati) furnished stream flow and drainage basin information and weather data.

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INTRODUCTION

On August 14, 1953, the Atomic Energy Commission requested the Environmental Health Center, U. S. Public Health Service, to submit a proposal for a study of the Scioto River and adjacent ground water as a source of potable water supply for the Atomic Energy Plant located near Piketon, Ohio. This proposal was submitted to the Commission under date of September 2, 1953. The proposal outlined a study program consisting of four principal items as follows:

Item I. Stream studies to assess the present pollution load in the Scioto River in the vicinity of the proposed intake at Piketon and at significant upstream points during conditions of (a) dry weather flow under late summer conditions, and (b) higher flow during winter conditions.

Item II. Studies to determine the ground water quality in the vicinity of Piketon including sanitary, chemical, physical, and bacteriological examinations.

Item III. Special studies related to raw water quality.

(a) Biological studies of the river water to determine the seasonal variations which may be expected in the algae population.

(b) Carbon filter studies to determine what groups of recoverable organic substances are present in both the river and ground water.

(c) Spectrographic analyses to determine metal elements in the water on a semiquantitative basis.

Item IV. Water Treatment Studies.

The Environmental Health Center was notified by telephone on September 15, 1953, to proceed with items I, II and III, reserving item IV until preliminary results are obtained and notification given to proceed on that item.

Field operations were initiated by Environmental Health Center personnel on September 18, 1953, under the general supervision of Sanitary Engineer D. D. Gold. Low water conditions prevailed continuously during the following weeks and sampling was discontinued on October 2, 1953. At a later date when relatively higher stream flows prevail field operations will again be resumed. This report has been prepared as an interim report covering the studies completed during low stream flows.

SYSTEM OF SAMPLING POINT DESIGNATION

A mileage index system is used to identify the location of sampling stations and important points on the Scioto River and its tributaries. This system involves the use of one or more letters to identify the stream, followed by a number which represents the distance in river miles from its mouth. In this report the letter "S" designates the Scioto River. For example, S-45.0 means that the station is located on the Scioto River 45.0 miles upstream from its mouth.

Each tributary to the Scioto River is designated by the first and second letters in its name. The first and second letters of the name of the tributary are preceded by the notation, "S-confluence mile." For example, S-62.5, Pa-1.5, would indicate that the station is located on Paint Creek 1.5 miles upstream from the confluence of Paint Creek and the Scioto River and that the point of confluence is 62.5 miles upstream from the mouth of the Scioto River.

The locations of sampling stations and other significant points on the Scioto River are listed in Table 1.

SCIOTO RIVER STUDIES

Purpose of Report

This report is based upon results of studies conducted in the Fall of 1953 during a period of low flow in the Scioto River. The principal purpose of this report is to present findings of fact and opinion in relation to the use of the Scioto River (at a point 34 miles from the mouth) as a source of raw water supply for the Atomic Energy Commission's Portsmouth Plant. Treated water from this source will be used for industrial purposes and its use for domestic purposes is under consideration. At present water for domestic purposes is obtained from wells located near the Scioto River about 29 miles from the mouth. Consequently data and discussion relating to ground water quality are also included.

Summary and Conclusions

Data were obtained regarding significant sources of pollution and existing water supplies in the Scioto River basin. Samples from four stations on the Scioto River including the water intake site were collected for 7 consecutive days and analyzed for the common parameters of pollution. Samples from the river at the intake site were similarly collected and analyzed every 2 hours for a 24-hour period. Additional samples were collected from various points on the Scioto River and from the major tributaries to obtain further information regarding the effects of industrial wastes and synthetic detergents on water quality. Special samples were collected for spectrographic, organic, and mineral analyses. Pertinent analyses were made on samples from the existing A.E.C. wells.

TABLE 1

SCIOTO RIVER STUDIES

LOCATIONS OF SAMPLING STATIONS, BRIDGES, TRIBUTARIES, ETC.

River Mile	Description of Station, Confluence, Etc.
S- 0	Confluence of Scioto River with Ohio River
S- 15.2	Lucasville Bridge, Route 348
S- 28.8	Approximate Location of A.E.C. Wells
S- 30.7	Piketon Sewer Outfall (approx.)
S- 30.8	Jasper Bridge, Route 124
S- 34.0	Sample Point #1, A.E.C. Intake Structure
S- 34.9	Piketon Bridge, Route U.S. 23
S- 38.6	Waverly Bridge, Route 220
S- 38.6	Waverly Sewer Outfall
S- 45.0	Sample Point #2, Omega Bridge, Route 335
S- 50.6	Salt Creek
S- 52.7	Approximate location of Miami Gravel Co.
S- 54.9	Sample Point #3, Higby Bridge
S- 62.5	Paint Creek
S- 63.4	Chillicothe Bridge, Route U. S. 35 & U. S. 50
S- 66.2	Chillicothe Sewer outfall
S- 69.2	Chillicothe Bridge, Route U. S. 23
S- 76.2	Sample Point #4
S- 83.3	Deer Creek
S- 97.8	Circleville Sewer outfall
S- 98.0	Circleville Bridge, Route U. S. 22
S- 99.0	Darby Creek
S-104.2	Walnut Creek
S-107.5	South Bloomfield Bridge, Route 316
S-115.3	Big Walnut Creek
S-118.1	Shadeville Bridge, Route 665
S-125.2	Columbus Sewer outfall
S-130.6	Olentangy River

I. Major Sources of Pollution

Municipal and industrial pollution equivalent to the wastes from over 500,000 persons (on a BOD basis) are contributed to the Scioto River from Columbus to the A.E.C. intake site. Major sources of pollution above the water intake are as follows:

Source	Waste Treatment	Major Significance from a Water Supply Standpoint
Columbus	Secondary	Organic pollution (BOD) plus fluoride from industrial processes
Fairfield Paper & Container Co.	None	Organic pollution (BOD)
Container Corp. of America	Secondary	Organic pollution (BOD)
Chillicothe	Primary	Organic pollution (BOD) and bacterial pollution
Mead Corporation	None	Organic pollution (BOD)
Waverly	Primary	Bacterial pollution

The Mead Corporation is the most significant contributor of organic pollution (BOD), because of its proximity to the intake and quantity of waste discharged . Waverly and Chillicothe are both significant contributors of bacterial pollution. Waverly is especially important because of its proximity to the intake. The outlook is for a substantial population increase at Waverly in the near future.

At the present time no water supplies are taken from the Scioto River below Columbus.

II. Water Quality

a. Bacteriological Quality - The Scioto River at the A.E.C. water intake site at low flows is significantly polluted from a bacterial standpoint.

Coliform concentrations found during the survey period exceed the criteria presented in the Public Health Service Manual of Water Sanitation Practice. (1) These criteria are:

(a) monthly average coliform concentrations not to exceed 5000/100 ml.

(b) coliform concentrations not to exceed 20,000/100 ml. in more than 5% of the samples.

These criteria were established on the basis of studies conducted about 25 years ago and are intended to serve as rough guides rather than inflexible rules. Many modern water treatment plants are successfully coping with greater bacterial loads without employing unusual treatment processes.

Coliform concentrations on all samples analyzed were quite high. Average coliform counts (MPN) for the 7 consecutive day sampling period were 29,000 per 100 ml., and for the 24-hour sampling period were 28,000 per 100 ml. The median coliform counts were 23,000 per 100 ml. in both cases. The maximum MPN value was 43,000 per 100 ml. and the minimum, 9,300.

Sewage discharged at Chillicothe and Waverly is especially significant from a bacteriological standpoint. Waverly sewage causes the high coliform count at the intake site. The proximity of the Waverly sewer outfall to the A.E.C. water intake allows very little time, even at low flows, for natural purification processes to reduce the bacterial load added by the Waverly sewage. Supplementary treatment (e.g. chlorination) of the Waverly primary treatment plant effluent would be desirable if the river is to be used as a source of domestic raw water supply.

b. Chemical Quality - The Scioto River at the A.E.C. water intake site is fairly highly mineralized at flows such as occurred during the Fall of 1953. Total dissolved solids exceeded 500 ppm. The total hardness was 343 ppm which is high but not excessive. The low non-carbonate hardness of the water makes it amenable to lime softening.

The fluoride content of the river at the intake was at or above the maximum permissible limit contained in the Public Health Service Drinking Water Standards (2) in all of the samples tested during the low flow period reported herein. The fluoride content of the water may be expected to be above the allowable limit of 1.5 ppm when the flow at the intake is less than approximately 450 cfs if the present discharge of fluoride containing wastes is continued. Sixty day mean flows of 450 cfs or less may be expected to occur on the average about once in five years. The high fluoride content of the stream is being further investigated by the Ohio Department of Health.

All other mineral constituents are within the maximum permissible or suggested limits for water supply purposes.

From 3.2 to 3.7 ppm of anionic detergent were found in the Scioto River at or near the intake site. This is probably sufficient to cause some water treatment difficulties and higher concentrations would almost certainly cause trouble (taste and odor and interference with coagulation).

The ammonia, nitrite, and nitrate nitrogen in the stream at the intake were not excessive for raw water supply. However, the high inorganic nitrogen concentration upstream was sufficient to encourage abundant plankton growths which may, at times, impart taste and odor to the water.

About 10 ppm of chlorine were required to produce a free chlorine residual.

Water from the A.E.C. wells is fairly hard but could be readily softened by lime treatment. The well water also contains excessive amounts of iron and manganese; however, these objectionable constituents could be removed by conventional water treatment processes. Treatment would be facilitated by the uniform nature of the water.

c. Physical Quality - Water from the Scioto River at the A.E.C. water intake was fairly high in color and turbidity. However, it is probable that both could be reduced to acceptable limits by appropriate water treatment. The temperature of the water showed a marked diurnal variation at the low flows encountered during the survey and reached 23°C. during the 24 hour sampling period. Higher temperatures can be expected at low flows during the summer months. (Temperatures above 27° C. are considered undesirable in a public water supply.)

The water had a noticeable odor (the median and maximum odor numbers were 96 and 256 respectively) and will probably be subject to more serious odor conditions at various times. Odor may be reduced by standard water treatment processes; however, the treatment of raw water high in odor and subject to periodic fluctuations in odor requires extensive treatment facilities, skilled supervision, comprehensive laboratory control, and may be quite expensive from a chemical cost standpoint.

The A.E.C. wells produced a cool water having no apparent odor.

d. Spectrographic Studies - Spectrographic analysis of samples from the Scioto River at the A.E.C. intake site and from the A.E.C. wells indicated that the heavy metals, with the exception of iron and manganese, were below the maximum allowable concentrations for finished waters.

e. Carbon Filter Studies - Organic materials recovered from carbon filters through which Scioto River water had been passed were equivalent to a concentration of 600 parts per billion. This is a significant concentration of such materials, being over ten times the concentration found in water known to be of good taste and odor quality. The recovered material was largely organic acids, neutral organic materials, and water soluble organic substances. These materials caused detectable odor at concentrations of 50 ppb. Phenols, which are commonly associated with taste and odor problems were not found in significant quantities.

Solutions containing 1 ppm of the total extract and of the various components separated were prepared in odor free tap water and dosed with 1 ppm of chlorine. This treatment did not significantly alter the taste or odor characteristics of the solutions. An appreciable concentration of these materials would probably pass through normal water treatment processes including free-residual (breakpoint) chlorination. Such materials may interfere with coagulation and cause other treatment difficulties. The concentration of these organic compounds could be reduced by the application of active carbon, but complete removal may be difficult or impracticable.

The possible health effects of the organic materials recovered from water are not known. However, as taste and odor in finished water may tend to cause the consumers to seek other sources without adequate regard for their safety, the distribution of a palatable water is a practical necessity.

The extract from the carbon filter placed at the A.E.C. wells showed 45 ppb of organic materials. Infrared absorption spectra indicated that the material recovered is probably largely lubricating oils though smaller amounts of the organic materials generally found in natural water were present. No particular significance is attached to the small quantity of material recovered.

d. Biological Quality - Phytoplankton and zooplankton were abundant in the Scioto River between Chillicothe and the A.E.C. water intake site. None of the algae commonly associated with severe taste and odor or filter clogging problems were abundant in the plankton during the September survey, but they may be more numerous at other times of the year. The diatoms, which are the algae most likely to cause filter clogging, would be expected to be most abundant in the spring of the year. The year-round study of the plankton which is now in progress will give more definite information on these points. The abundant phytoplankton represented possible water treatment problems despite the fact that no algae commonly known as nuisance organisms were numerous. The extreme abundance of any algal form can result in nuisance conditions.

Extensive growths of attached and floating algae were present in many areas in the portion of stream surveyed. Bottom growths of "sewage fungus" were present in the areas below the entrance of pollution from

Chillicothe and Paint Creek. These growths represent potential operational problems as increased flow could carry much of this material downstream to the intake area. Death and decay of these masses could also cause taste and odor in the raw water.

Both the carbon filter studies and the biological studies indicate that it is highly probable that serious taste and odor difficulties will be encountered in the treatment of water from the Scioto River.

Comparison of Sources of Raw Water Supply (Domestic Use)

	Scioto River Water	Ground Water (Existing Wells)
Raw Water Characteristics		
Organic matter	High	Low
Coliform bacteria	High	Low
Odor and color	High	Very low
Mineral	High concentrations of fluoride at times.	Fluoride concentration low. Fe & Mn easily removed.
Treatment Problems		
Raw water quality	Variable - probably rapid and extreme changes in quality.	Relatively constant
Supervision	Unusually careful supervision and laboratory control.	Average supervision and laboratory control.
Finished Water Quality	Bacteriologically safe but difficult to produce a consistently palatable water. Fluoride too high during low flow periods.	Bacteriologically safe. Probably no taste and odor difficulties. No fluoride problem.
Chemical Costs	Probably fairly high	Moderate

Recommendations

On the basis of the previously summarized data and the conclusions pertinent thereto, it is recommended that

(1) Provided a sufficient quantity of water can be obtained the Atomic Energy Commission seriously consider using the ground water resources of the area rather than the Scioto River as a source of domestic water supply.

(2) That the ground water be subjected to treatment as necessary to improve its chemical and bacteriological quality.

SECTION I - SANITARY SURVEY

DESCRIPTION OF SCIOTO RIVER BASIN

Physical (3) (4)

The Scioto River, a tributary of the Ohio, drains an area of 6,510 square miles in south central Ohio. The basin, as shown in Figure 1, is roughly rectangular in shape and extends in a narrow band about 50 miles wide for a distance of 130 miles north from the Ohio River. It is bounded principally by the Miami and Little Miami watersheds on the west, the Sandusky and Maumee watersheds on the north and the Muskingum and Hocking watersheds on the east. The major tributaries are the Olentangy River, Big Walnut Creek, Walnut Creek, Big Darby Creek, Deer Creek, Paint Creek, and Salt Creek.

The area north of Chillicothe, which is in the Till Plains section of the Central Lowland province, is glaciated and generally level to gently rolling in character. The valley proper averages about 12 miles in width below Columbus and forms a very fertile and rich agricultural region.

The area south of Chillicothe, which is in the Kanawha section of the Appalachian Plateaus province, is an unglaciated area rugged in character with steep slopes of shale and soft sandstone which give rapid rates of runoff. The original plateau has been deeply dissected by streams until it consists generally of narrow ridges and steep sided valleys with depths as great as 500 feet. The valleys, except for that of the Scioto, which is generally 1.5 to 2.0 miles wide, are narrow and the streams have very narrow flood plains or no flood plains. The Scioto

River lies in the valley of a preglacial river which has been filled with glacial outwash to a depth of 100 to 250 feet, forming an extensive reservoir for underground water.

The tract selected by the Atomic Energy Commission lies in Pike County in the unglaciated area approximately 35 river miles below Chillicothe and just east of the valley proper.

Economic Development (5)

Agriculture is the predominate industry in the Scioto River basin. Other industries of major importance are paper mills and canneries. Industries of lesser importance include metal fabricating, rendering and manufacture of machinery, chemicals, furniture, textiles, fabricated textiles, leather goods, clay products, concrete products, lumber products, slauthtering products and dairy products.

Population (3) (5)

The 1940 population of the Scioto watershed was about 740,000 of which 306,000 live in Columbus. Estimates based on the 1950 census indicate a population for the Scioto basin of about 880,000 and a population for Columbus of about 376,000. Exclusive of Franklin County the average population density of the basin is about 61 persons per square mile. Pike County had a 1950 population of 14,607 or 33 persons per square mile. Estimates of the number of workmen living in Pike County indicate that the population may now be over 50,000.

Reservoirs and Diversion Projects

The City of Columbus has built the Griggs and O'Shaughnessy Dams on

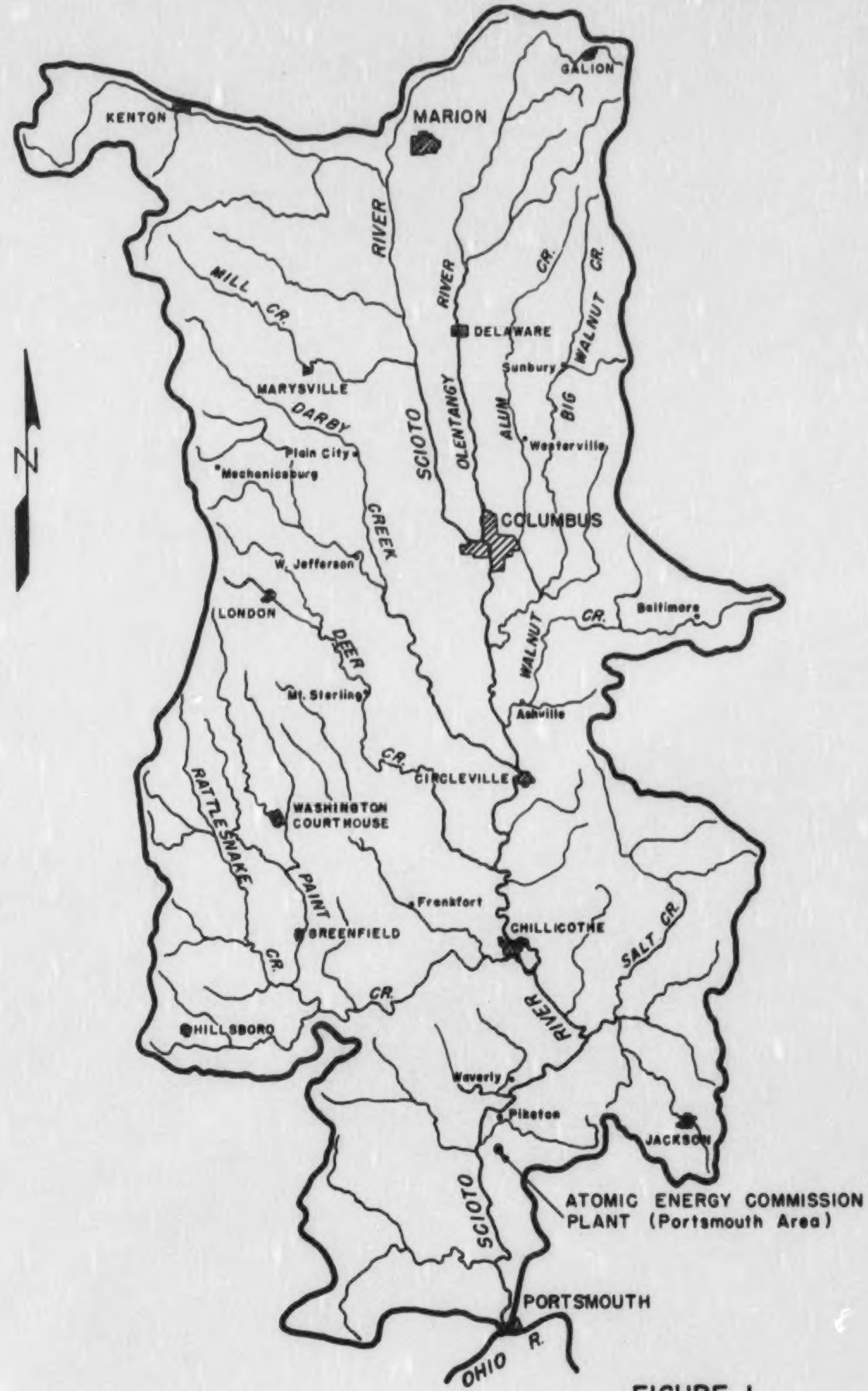


FIGURE I

GENERAL REFERENCE MAP
SCIOTO RIVER BASIN

5 0 5 10
SCALE OF MILES

the Scioto River to provide storage for water supply purposes. A third dam is presently contemplated on the Olentangy River above Columbus (5).

A flood control dam has been constructed on the Olentangy River above Delaware, Ohio, and is the only flood control dam in the basin. The Corps of Engineers, Department of the Army, has proposed additional control dams on Big Darby Creek, Deer Creek, Paint Creek, and Rocky Fork, in their comprehensive flood control plan for the Ohio Valley (6).

There are no hydroelectric developments on the river and the river is not navigable.

Recreation, Fish, and Wildlife

Restricted recreational developments are present on the Scioto River below Columbus (7).South of Chillicothe more extensive use is made of the valley for recreational purposes including a number of State Parks, forests and artificial lakes within a 30 mile radius of the A.E.C. site. There is no commercial fishing on the Scioto River. However, fishing by sportsmen was observed on some of the major tributaries. Abundant cover is available for wildlife in the lower valley.

Temperature (4)

Ohio usually has moderate temperatures. The annual average air temperature for the State is about 51° F. At Waverly the average annual temperature from 1920 to 1945 was 54.8° F. The average monthly temperature varies from 33° F. in January to 75.4° F. in July. The minimum recorded temperature was 29° F. below zero, and the maximum recorded was 107° F. During an earlier survey (3) of the Scioto River it was found that the river temperature followed rather closely the running average of the mean daily air temperatures for the preceding several days. At extreme low flows as occurred during this survey the water temperature may have a marked diurnal variation.

Hydrology (4) (5)

The average annual precipitation in the basin is about 38 inches, the precipitation being slightly greater in the southern part of the valley than in the northern part. The rainfall is generally above the average for the year in January and from March through August and below the average for the rest of the year. For the 65 year period up to 1947 the maximum and minimum monthly precipitations were about 20 percent above and below the average, respectively. However, as has been illustrated this summer and fall (1953) the rainfall in any year may vary widely from the 65 year average.

Flow data at 25 stream gaging locations are currently reported by the U. S. Geological Survey. Stream flows vary between wide extremes. Low flows below Columbus on the Scioto River are now regulated by the Columbus water supply reservoirs on the Scioto River and the flood control reservoir on the Olentangy River.

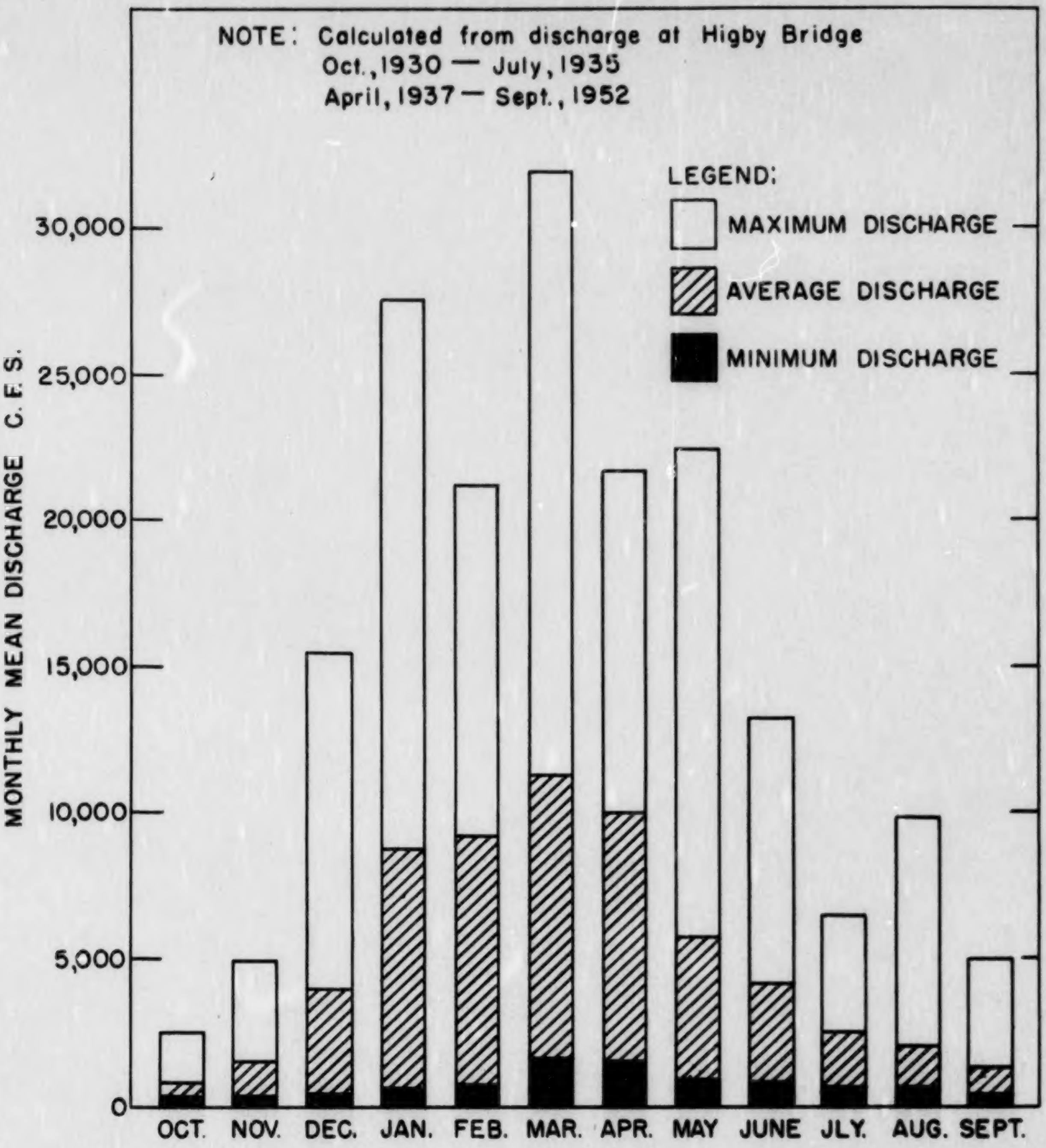
Stream flow data from gaging stations on the Scioto River are contained in the annual Water-Supply Papers of the United States Geological Survey. A compilation and condensation of these records has been published by the Division of Water of the Ohio Department of Natural Resources (8) (9).

Stream gaging stations have been maintained on the Scioto River and its tributaries since the early twenties. The earliest station was established at Chillicothe in 1921. Supplementary stations have been established since that time, including one at Higby in 1931, and at Circleville in 1939. In the discussion which follows it is assumed that the discharge per unit area of the watershed at the indicated gaging station is applicable to the river at the A.E.C. water intake unless specified otherwise. The close agreement of the flow estimates of the river at the water intake site based on the flow duration curves at Chillicothe, Higby, and Circleville supports this assumption. The mean annual discharge at the water intake is approximately 5110 cfs (1930-1952) and is at or below 1800 cfs 50% of the time (1931-1945). The estimated minimum, average, and maximum mean monthly discharge rates at the water intake are presented in Figure 2. As indicated on the figure, this estimate is based on discharge records at the Higby Bridge gage.

Stream flow data for the Chillicothe and Higby gages and the rating curves (Figure 3) have been secured from the U. S. Geological Survey office in Columbus. The discharges at S-45.0 (Omega Bridge) and at the A.E.C. water intake have been estimated on the basis of the discharge at the Higby gage. Estimates based on the discharge at Chillicothe plus the 1952 average waste discharge of the Mead Corporation are in fairly close agreement with those based on the Higby gage. During the period of the survey the river discharge averaged between 300 and 320 cfs at the A.E.C. water intake.

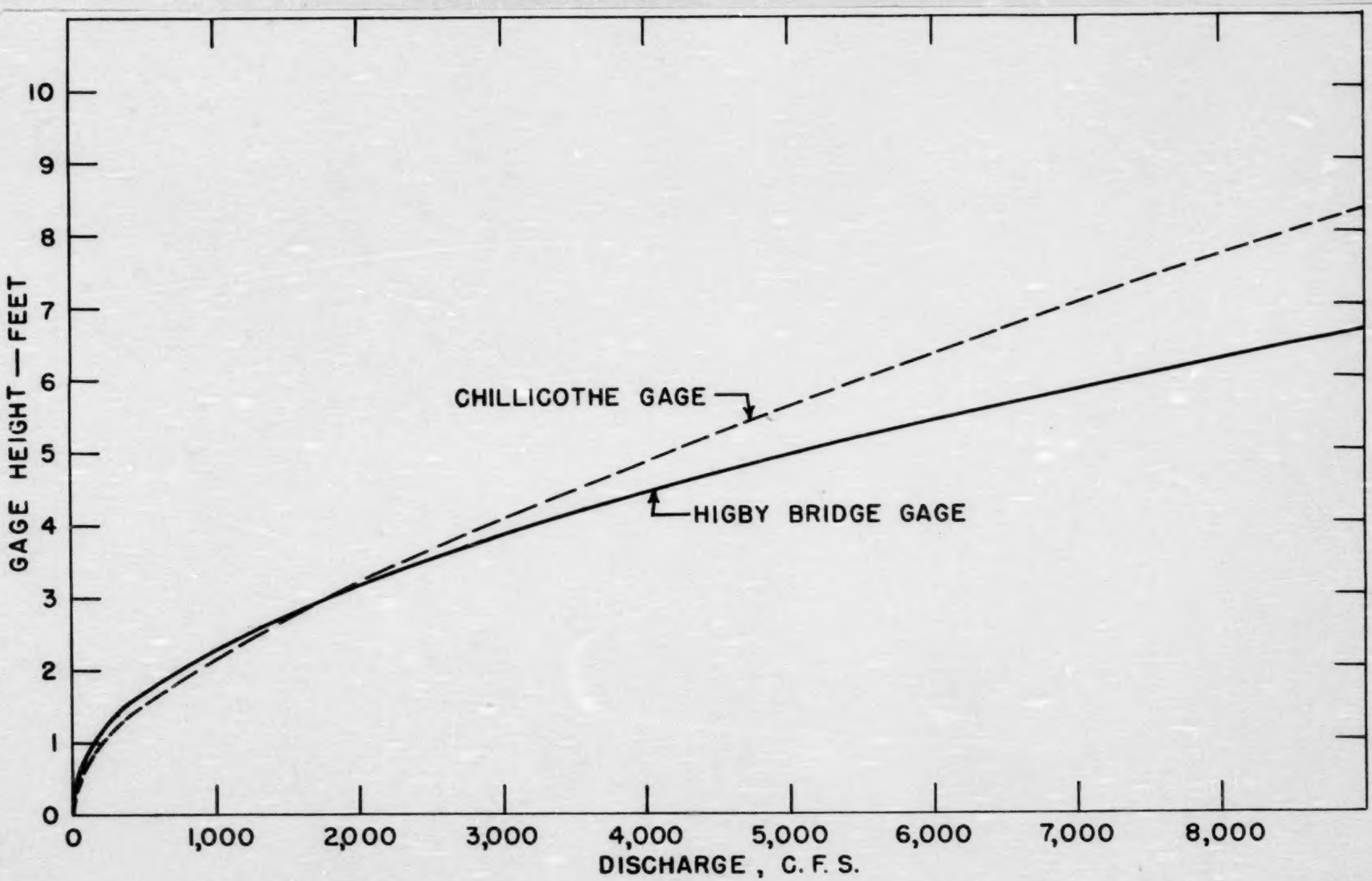
Low flow frequency curves for river discharge at the intake structure location based on data from the Chillicothe gage (9) are presented in Figure 4. Since the Mead Corporation obtains its water supply from wells, the curves appearing as dashed lines on Figure 4 include the addition of a uniform discharge of 34 cfs (the average daily waste discharge rate of the Mead Corporation during 1952). On the basis of the modified curve (dashed line), droughts having as low a flow as existed during the survey and extending over a similar period of time should be expected no oftener than once in over 25 years.

The minimum discharge of record at Higby was 244 cfs. The lowest discharge at the intake structure may have been of the order of 280 cfs.



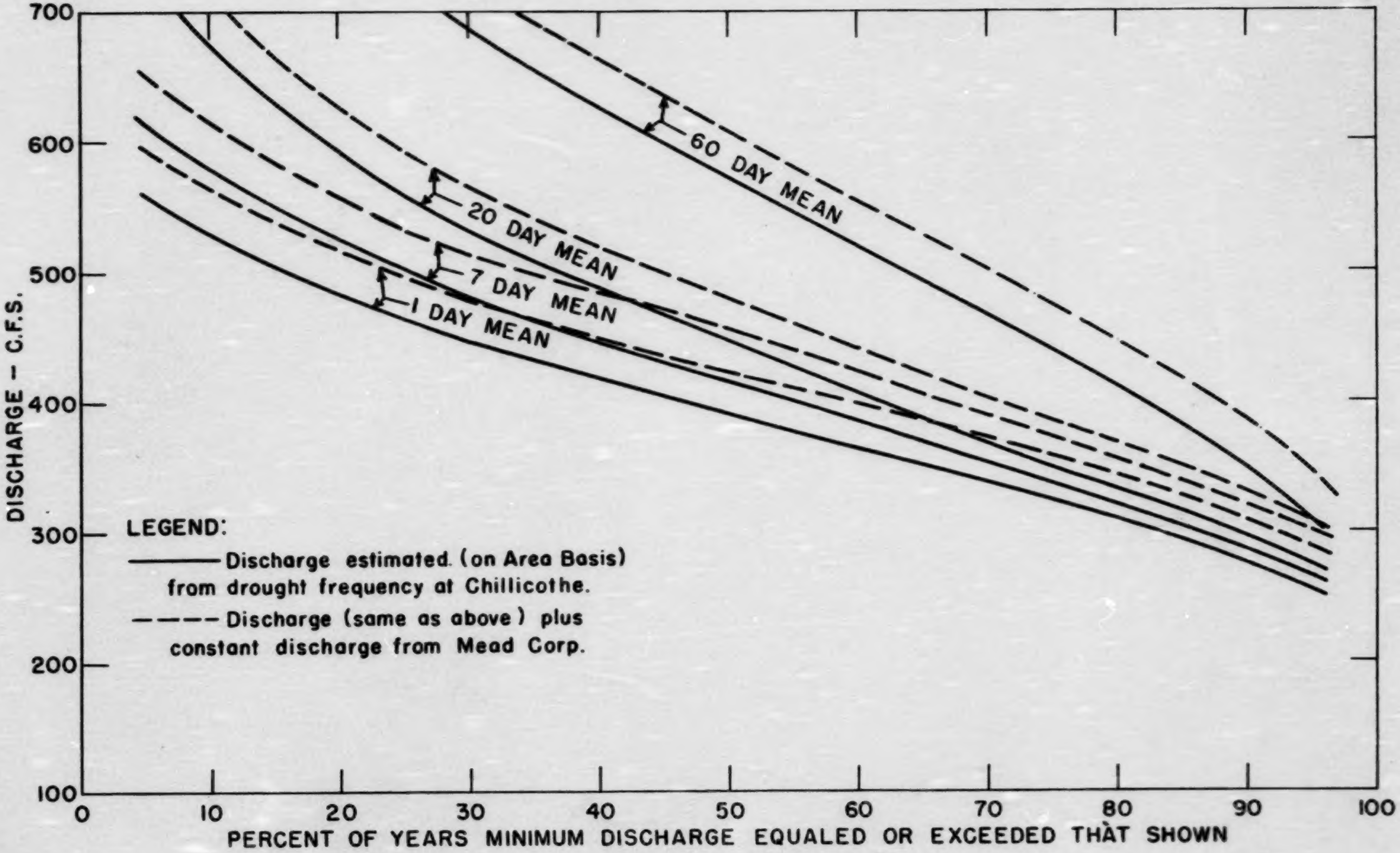
AVERAGE, MAXIMUM, AND MINIMUM MONTHLY DISCHARGE
SCIOTO RIVER AT A.E.C. WATER INTAKE (S-34.0)

FIGURE 2



DISCHARGE CURVES
DATA FROM U.S.G.S. COLUMBUS, OHIO

FIGURE 3



LOW FLOW FREQUENCY
SCIOTO RIVER AT A.E.C. INTAKE

FIGURE 4

SURFACE WATER SUPPLIES

The nine water supplies derived from surface sources in the Scioto River Basin are listed in Table 2. The Columbus water supply is the largest, serving a population of over 400,000. The remaining eight surface supplies serve a population of about 41,000.

Most of the major sources of pollution above Columbus receive treatment. Storage on the Scioto acts as an additional safeguard. In general, the other supplies are protected by distance or treatment from small upstream sources of pollution.

At present there are no water supplies on the Scioto River below Columbus. Data collected on the Ohio River Pollution Control Survey in 1939 (8) indicated high coliform bacteria counts at Higby and Waverly and indicated average coliform MPN results in excess of 20,000 per 100 ml. at all stations below Columbus.

SOURCES OF POLLUTION

The known sources of pollution on the Scioto River and its tributaries from Columbus to the A.E.C. water intake are shown on Figures 5 and 6 and listed in Table 3 (7) (10). The amount of wastes discharged to the stream and the type of discharge, whether municipal or one of several industries, is indicated in Figure 5.

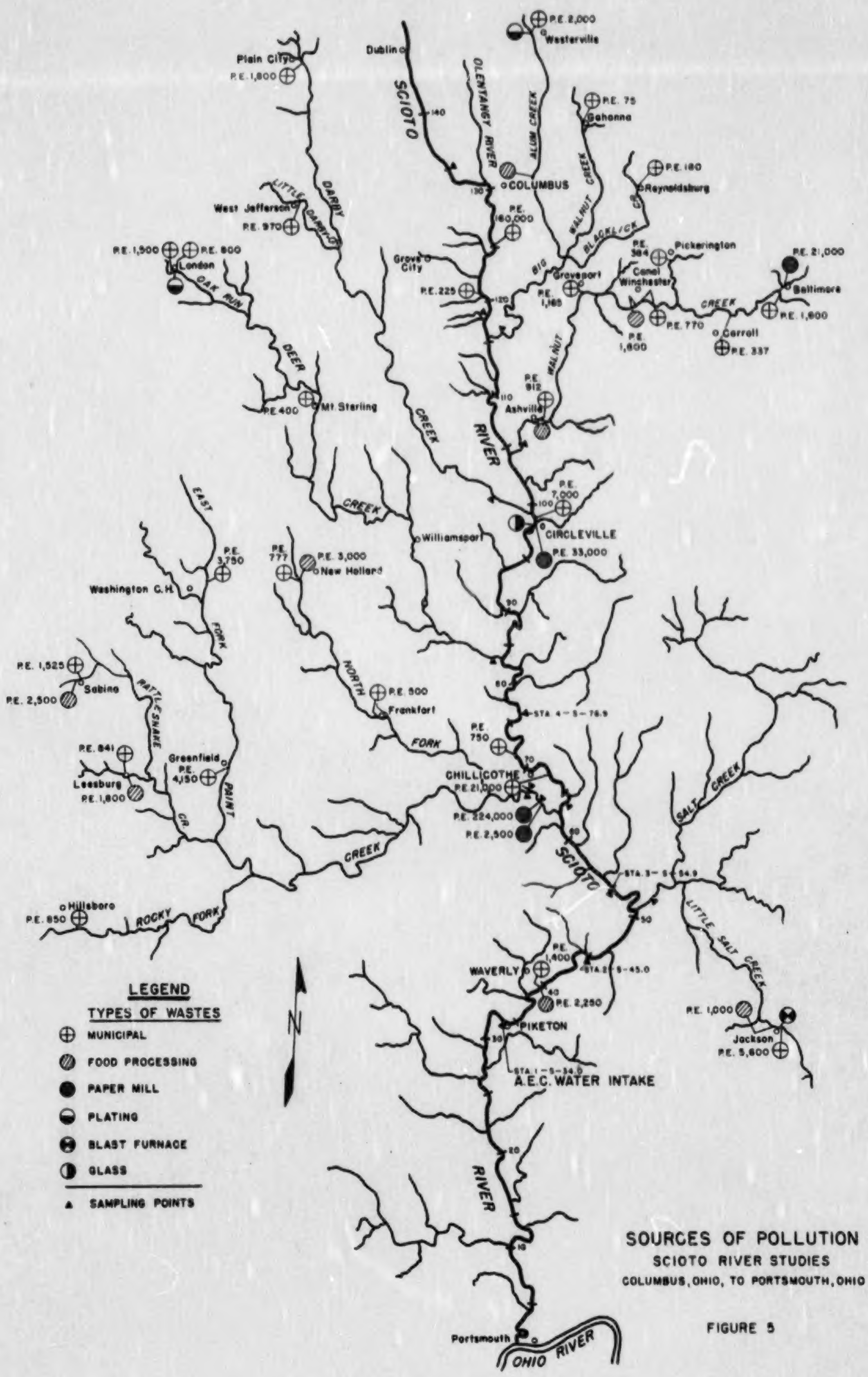
The largest sources of pollution on the Scioto River and its tributaries are the cities of Columbus and Chillicothe and the Fairfield Paper and Container Company at Baltimore, the Container Corporation of America at Circleville, and the Mead Corporation at Chillicothe. These sources contribute a waste load having an estimated population equivalent of about 460,000 which is about 90 percent of the waste discharged to streams in the area considered. From a water supply standpoint the most important sources of pollution are the town of Waverly, the city of Chillicothe and the Mead Corporation. Present plans indicate that all sanitary sewage from the town of Piketon will be discharged below the water intake near Route 124 Highway Bridge. The proximity of the Waverly outfall to the intake allows but little time for natural purification processes to reduce the bacterial pollution. There are at least six manufacturing plants above the intake (exclusive of Columbus) which might at one time or another discharge chemical wastes containing fluoride.

TABLE 2

SCIOTO RIVER STUDIES

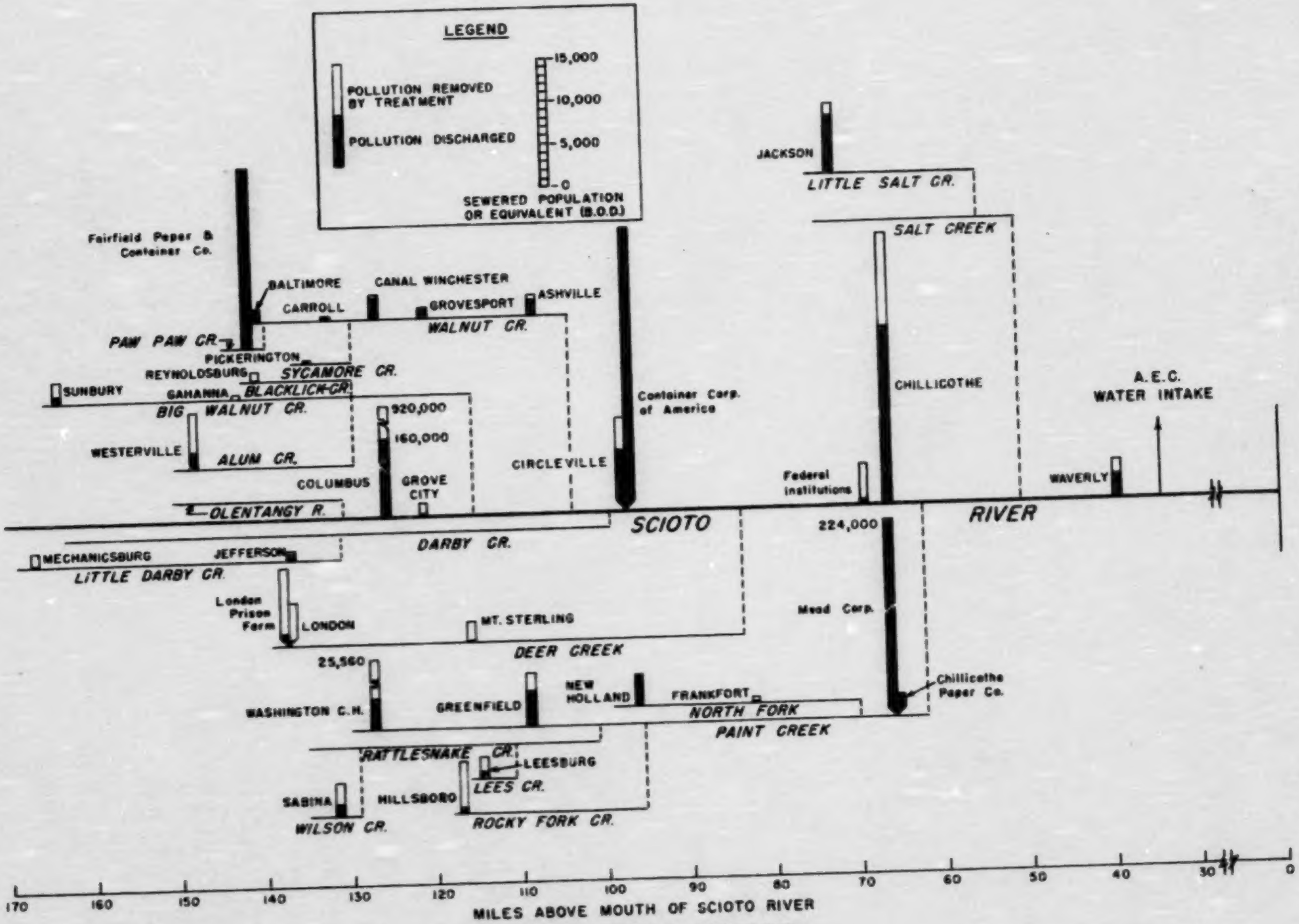
SURFACE WATER SUPPLIES IN THE SCIOTO RIVER BASIN

City	Source	Estimated Population Served	Average Plant Output MGD
Caledonia	Olentangy	-	0.020
Columbus	Scioto River	400,000	47.0
Delaware	Olentangy River	11,500	1.33
Delaware County Girls Industrial School	Scioto River	5,000	-
Galion	Whetstone Creek	10,000	0.75
Hillsboro	Rocky Fork Creek	5,100	0.29
Marysville	Mill Creek + wells	4,000	0.48
Sunbury	Big Walnut Creek	900	0.11
Westerville	Alum Creek + wells	4,000	0.28



SOURCES OF POLLUTION
SCIOTO RIVER STUDIES
COLUMBUS, OHIO, TO PORTSMOUTH, OHIO

FIGURE 5



SCIOTO RIVER STUDIES

SOURCES OF POLLUTION BETWEEN
COLUMBUS AND A.E.C. WATER INTAKE

FIGURE 6

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Cincinnati, Ohio

TABLE 3
SCIOTO RIVER STUDIES
SOURCES OF POLLUTION
BETWEEN COLUMBUS AND A.E.C. WATER INTAKE

No.	Municipality or Industry	Receiving Stream	Miles to Mouth		Population Connected to Sewers (1950)	Sewage Treatment	Population Equivalent*		Remarks
			Scioto	Trib.			Before Treatment	Discharged to Receiving Stream	
1	Columbus	Scioto	125.2		450,000	Secondary	920,000	160,000	1953 Summer conditions. Plant overloaded.
2	Crove City	Scioto	120.7		1,500	Secondary	1,500	225	
		Big Walnut Cr.	115.0						
		Walnut Creek	103.8						
		Darby Creek	98.7						
3	Circleville	Scioto River	97.8		8,700	Primary	10,900	7,000	
	Pickaway Dairy Co-op Assn.	See Remarks						(400)	To Circleville Sewage System
	Esmeralda Canning Co.	"						(600)	"
	Winorr Canning Co.	"						(1,200)	"
	Maizo Mills Co. (abrasives)	"						-	"
	General Electric Co. (Electric Lamps)	"						-	"
4	Container Corp. of America	Scioto	97.8			Secondary	Unknown	33,000	
		Deer Creek	83.1						

TABLE 3 (Cont'd-2)

No.	Municipality or Industry	Receiving Stream	Miles to Mouth		Population Connected to Sewers (1950)	Sewage Treatment	Population Equivalent*		Remarks
			Scioto	Trib.			Before Treatment	Discharged to Receiving Stream	
5	Federal Institutions	Scioto	69.3		5,000	Secondary	5,000	750	Design load
6	Chillicothe	Scioto	66.2		22,000	Primary	32,000	21,000	1952 - average load
	Chillicothe Pure Milk Co.	See Remarks						(1,000)	To Chillicothe Sewage System
	Hunn, Charles J. (meat packing)	"						(2,700)	"
	Home Dairy	"						(100)	"
	Janes, A. & Sons (rendering)	"				Unknown	Unknown	Unknown	"
		Paint Creek	62.5						
7	Miami Gravel Co.	Scioto	52.7			-	-	-	
		Salt Creek	50.5						
8	Waverly	Scioto River	38.6		2,000 est.	Primary	2,000	1,400	Population of 5000 expected this year
9	(Poultry)	See Remarks				None	2,250	2,250	Near Waverly
10	Piketon	Scioto River	30.7						Population of 4,000 expected (discharge to be below A.E.C. water intake)

TABLE 3 (Cont'd-3)

No.	Municipality or Industry	Receiving Stream	Miles to Mouth		Population Connected to Sewers (1950)	Sewage Treatment	Population Equivalent*		Remarks
			Scioto	Trib.			Before Treatment	Discharged to Receiving Stream	
11	Sunbury	Big Walnut Cr.	115	48.5	936	Secondary	2,636	900	
	Nestle Co., Inc. (candy)	See Remarks						(1,700)	To Sunbury Sewage System
12	Gahanna	Big Walnut Cr.	115	27.4	526	Secondary	526	75	
		Blacklick Cr.	115	14.0					
		Alum Cr.	115	14.0					
13	Reynoldsburg	Blacklick Cr.		11.1	724	Secondary	1,224	180	
14	Westerville	Alum Cr.		18.9	4,112	Secondary	6,712	2,000	
	Westerville Creamery Co.	See Remarks						(2,100)	To Westerville Sewage System
	Kilgore Mfg. Co. (electroplating)	"				-	-	-	"
15	E. G. Buchsieb (rendering)	Alum Cr.		6.1		Unknown	Unknown	Unknown	
16	Baltimore	Walnut Cr.	103.8	36.1	1,600	None	1,600	1,600	
		Paw Paw Cr.	103.8	35.6					
17	Carroll	Walnut Cr.	103.8	28.0	337	None	337	337	
		Sycamore Cr.	103.8	25.2					
18	Canal Winchester	Walnut Cr.	103.8	22.4	1,187	Primary	1,187	770	
	Standard Glass Mfg. Co.	See Remarks				-	-	-	To Canal Winchester Sewers

TABLE 3 (Cont'd-4)

No.	Municipality or Industry	Receiving Stream	Miles to Mouth		Population Connected to Sewers (1950)	Sewage Treatment	Population Equivalent*		Remarks
			Scioto	Trib.			Before Treatment	Discharged to Receiving Stream	
19	Winchester Canning Co.	Walnut Cr.	103.8	22.4		None	1,800	1,800	
20	Groveport	Walnut Cr.	103.8	16.5		None	1,165	1,165	
21	Ashville	Walnut Cr.	103.8	3.8	1,303	Primary	1,403	912	
	Pickaway Dehydrating Co-op	See Remarks						(100)	To Ashville Sewage System
22	Crites Milling Co.	Walnut Cr.	103.8	3.8		Unknown	Unknown	Unknown	
23	Fairfield Paper & Container Co.	Paw Paw Cr.		1.0		None	21,000	21,000	Near Baltimore
24	Pickerington	Sycamore Cr.		5.1	384	None	384	384	
25	Pickerington Creamery, Inc.					Land Irrigation			Near Pickerington
26	Milford Center	Darby Cr.	98.7	62.2	753	None	753	753	
27	Plain City	Darby Cr.	98.7	49.1	1,715	Secondary	3,965	1,800	
	Stokely Food Co. (canning)	See Remarks						(2,250)	To Plain City Sewage System
		Little Darby Cr.	98.7	32.2					
28	Mechanicsburg	Little Darby Cr.		35.8	1,920	Secondary	1,920	300	
29	Jefferson	Little Darby Cr.		5.7	1,386	Primary	1,386	970	
30	London Prison Farm	Deer Creek	83.1	53.9	1,900	Secondary	9,335	1,500	

TABLE 3 (Cont'd-5)

No.	Municipality or Industry	Receiving Stream	Miles to Mouth		Population Connected to Sewers (1950)	Sewage Treatment	Population Equivalent*		Remarks
			Scioto	Trib.			Before Treatment	Discharged to Receiving Stream	
31	London	Deer Creek	83.1	53.1	5,220	Secondary	5,720	800	
	London Creamery Co.	See Remarks						(500)	To London Sewage System
	Williams Co.	"						(-)	"
32	Armstrong Metal Prod.	Deer Creek	83.1	53.1				(-)	
33	Mt. Sterling	Deer Creek	83.1	32.6	1,172	Secondary	2,672	400	
34	Washington Court House	Paint Creek	62.5	65.2	10,560	Secondary	25,560	3,750	
	Cudahy Packing Co.	See Remarks						(12,000)	To Washington C. H. Sewage System
	Consolidated Prod. Co. (condensed milk)	"						(200)	"
	Weade, John M. & Son (Abattoir)	"						(1,000)	"
	Hamm, M. Co. (fertilizers)	"						(-)	"
35	Greenfield	Paint Creek	62.5	45.8	4,862	Primary	6,362	4,150	
		Rattlesnake Cr.	62.5	39.8					
		Rocky Fork	62.5	34.3					
		North Fork	62.5	7.8					

TABLE 3 (Cont'd-6)

No.	Municipality or Industry	Receiving Stream	Miles to Mouth		Population Connected to Sewers (1950)	Sewage Treatment	Population Equivalent*		Remarks
			Scioto	Trib.			Before Treatment	Discharged to Receiving Stream	
36	Mead Corporation	Paint Creek	62.5	3.0		None	224,000	224,000	
37	Chillicothe Paper Co.	Paint Creek	62.5	3.0		None	2,500	2,500	
		Wilson Creek		26.9					Tributary to Rattlesnake Creek
		Lees Creek		9.0					"
38	Sabina	Wilson Creek		2.8	1,525	None	1,525	1,525	
39	C.W.Swain Canning Co.	Wilson Creek		2.8		None	2,500	2,500	
40	Leesburg	Lees Creek		3.7	841	None	841	841	
41	Highland Canning Co.	Lees Creek		3.7		None	1,800	1,800	
42	Hillsboro	Rocky Fork		20.6	5,126	Secondary	6,126	850	
	Swanger Dairy	See Remarks						(300)	To Hillsboro Sewage System
	Carnation Co.	See Remarks						(700)	"
43	New Holland	North Fork		26.3	777	None	777	777	
44	Crites Milling Co. (canning)	North Fork		26.3		None	3,000	3,000	
45	Frankfort	North Fork		12.4	869	Primary	869	500	
		Little Salt Cr.	50.5	4.4					Tributary to Salt Creek

TABLE 3 (Cont'd-7)

No.	Municipality or Industry	Receiving Stream	Miles to Mouth		Population Connected to Sewers (1950)	Sewage Treatment	Population Equivalent*		Remarks
			Scioto	Trib.			Before Treatment	Discharged to Receiving Stream	
46	Jackson	Little Salt Cr.		17.3	7,000	Primary	7,250	5,000	
	Green Valley Dairy	See Remarks						(250)	To Jackson Sewage System
47	Globe Iron Co.	Little Salt Cr.		17.3				-	
48	Jackson Iron & Steel Co.	Little Salt Cr.		17.3				-	
49	Cambria Packing Co.	Little Salt Cr.		17.3		None	1,000	1,000	

* Includes Industrial Wastes

SURVEY METHODS

Sampling Points and Their Location - The survey group concentrated on the following four stations: S-34.0 (A.E.C. water intake structure), S-45.0 (Omega Bridge), S-54.9 (Higby Bridge) and S-76.2 (above Chillicothe). Other sampling stations were used occasionally on tributaries for chemical and bacteriological samples (shown on Figure 5). At the low flows during the period of sampling the velocity of the river and its twisting path indicated that vertical and horizontal mixing were sufficient to afford complete mixing of pollutional discharges by the time they reached the sampling stations.

Nearly all sampling stations were selected at or near bridges so that during subsequent sampling at high flows samples could be obtained by sampling from bridges. At the low flows existing during this period of the studies, sampling personnel could wade into the river and obtain the samples. The stations were also selected so that they were sufficiently downstream from sources of pollution for adequate mixing to occur throughout the stream cross section.

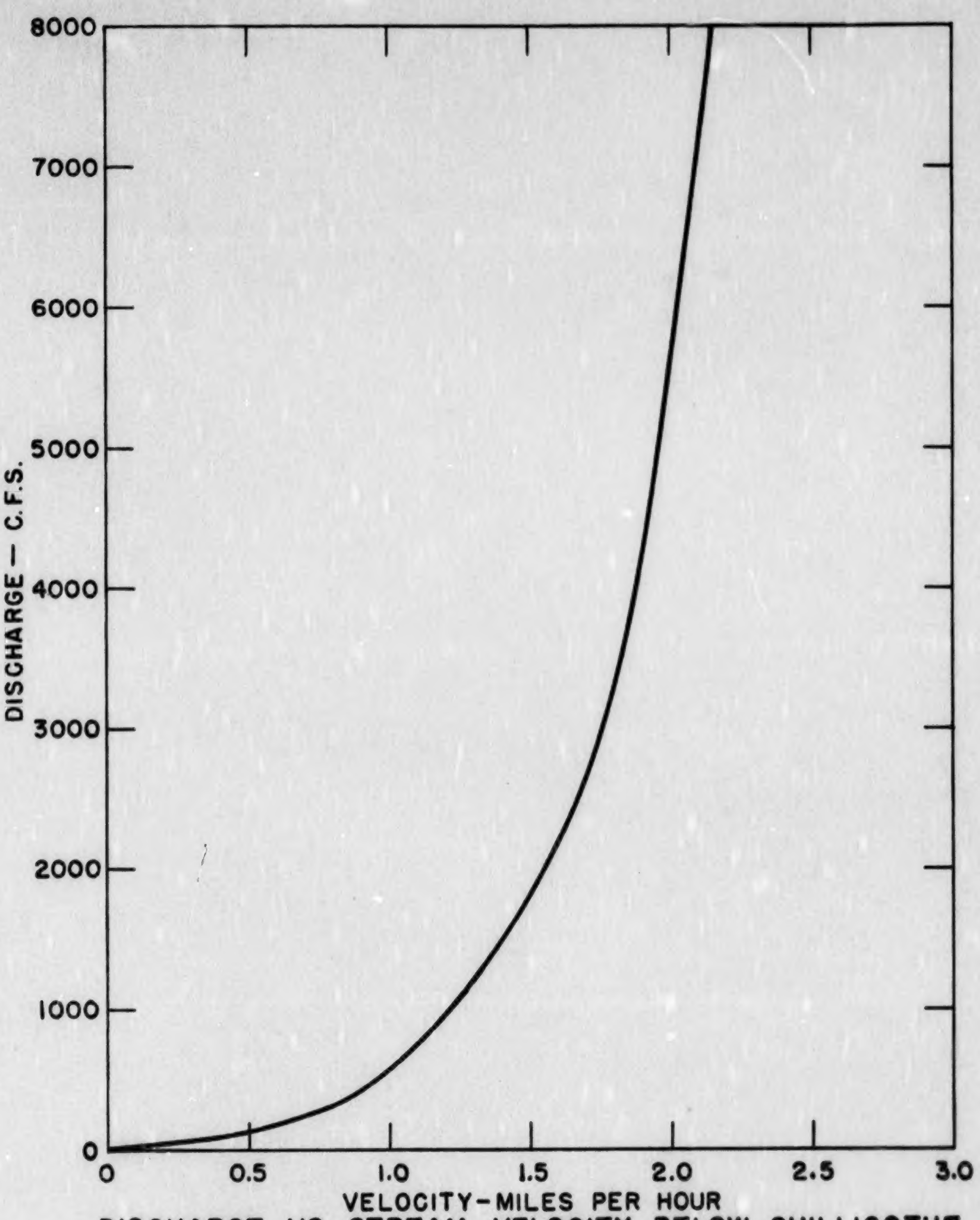
Sampling Procedure - Sampling was performed to secure a representative portion of the stream at each sampling station. Stream samples for physical and chemical analysis were taken at mid-depth in the middle of the channel. Samples for bacteriological analysis were taken at a six inch depth.

The sample collector recorded the time of day when a sample was collected, determined the temperature of the water sampled, and recorded as "remarks" any unusual stream conditions.

DETERMINATION OF FLOW TIME

Flow time for various Scioto River discharges (between Chillicothe and the A.E.C. water intake) were calculated from the velocity-discharge curve shown in Figure 7. This curve was developed from data presented in Public Health Bulletin No. 276, p. 19 (3), from U. S. Geological Survey data from gaging stations at Circleville, Chillicothe, Higby, and Waverly, Ohio, and from float studies performed by Public Health Service personnel on a stream stretch above the intake. The curve was passed through a point determined by the float studies and drawn roughly parallel to the curve presented in the previously mentioned Public Health Bulletin No. 276.

Flow times between stations and from these stations to the A.E.C. water intake are presented in Table 4.



DISCHARGE VS. STREAM VELOCITY BELOW CHILLICOTHE
SCIOTO RIVER STUDIES

FIGURE 7

TABLE 4

ESTIMATED FLOW TIME

				Flow Time	
Station	**Discharge** cfs	Mean **Discharge** cfs	Mean **Velocity** mi./hr.	From Previous Station **Hours**	To Water Intake **Hours**
Chillicothe Sewer S-66.2	200				42.6
	330				34.7
	660				28.1
	1320				21.8
	1980				19.2
(Dist = 2.8 mi)	3300				17.0
	6600				14.6
Chillicothe S-63.4	200	200	0.65	4.3	38.3
	330	330	0.84	3.3	31.4
	660	660	1.05	2.7	25.5
	1320	1320	1.33	2.1	19.7
	1980	1980	1.54	1.8	17.3
(Dist = 8.5 mi)	3300	3300	1.79	1.6	15.4
	6600	6600	2.05	1.4	13.3
Higby Bridge S-54.9	265	233	0.73	11.6	26.6
	440	385	0.92	9.2	22.1
	880	770	1.10	7.7	17.7
	1760	1540	1.42	6.0	13.7
	2640	2310	1.62	5.2	12.1
(Dist = 16.3 mi)	4400	3850	1.84	4.6	10.8
	8800	7700	2.13	4.0	9.3
Waverly Sewer S-38.6	295	280	0.78	20.9	5.8
	495	468	0.94	17.3	4.8
	990	935	1.17	13.9	3.8
	1980	1870	1.52	10.7	3.0
	2950	2795	1.72	9.5	2.6
(Dist = 4.6 mi)	4950	4675	1.94	8.4	2.4
	9900	9350	2.25	7.2	2.0
AEC Water Intake S-24.0	300	298	0.80	5.8	
	500	498	0.95	4.8	
	1000	995	1.20	3.8	
	2000	1990	1.54	3.0	
	3000	2975	1.75	2.6	
(Dist = 18.8 mi)	5000	4975	1.94	2.4	
	10000	9950	2.28	2.0	
Lucasville Bridge S-15.2	305	302	0.80	23.5	
	510	505	0.95	19.8	
	1020	1010	1.21	15.5	
	2040	2020	1.55	12.1	
	3060	3030	1.76	10.7	
	5100	5050	1.94	9.7	
	10200	10100	2.28	8.2	

PRESENTATION OF DATA

The individual results of the sanitary examination of samples collected at S-34.0 (A.E.C. water intake), S-45.0 (Omega Bridge), S-54.9 (Higby Bridge), and S-76.2 from September 23 to September 29 are presented in Table 5. The average results of selected determinations at the four stations are presented graphically in Figure 8. Results of chlorination studies are presented in Table 6 and in Figure 9.

Data from the examination of samples collected at 2 hour intervals during a 24 hour period on September 30, 1953, at the A.E.C. water intake are presented in Table 7. The results of selected determinations are presented graphically in Figure 10.

The results of two mineral analyses of Scioto River water at S-34.0 (A.E.C. water intake) and one mineral analysis of water from the A.E.C. wells are presented in Table 8. Results of analyses of water samples by the U.S.G.S. and the Ohio Department of Health (4) (11) on the A.E.C. well and the Waverly well and on the Scioto River at Chillicothe and Higby are also presented in Table 8 for comparison.

Results of miscellaneous tests on a number of samples collected during the survey are presented in Table 9. Graphs illustrating variations of concentrations of fluoride, chloride, alkalinity, and dissolved solids with discharge are shown in Figures 11, 12, 13 and 14, respectively.

ANALYSES PERFORMED AND THEIR SIGNIFICANCE

Laboratory Tests - The routine laboratory tests included temperature, dissolved oxygen, biochemical oxygen demand, ammonia nitrogen, nitrite nitrogen, nitrate nitrogen, color, turbidity, total suspended solids, total volatile suspended solids, pH, alkalinity, coliform MPN and total bacteria on agar at 37° C. Chlorine demand, free residual (breakpoint) chlorination, chloride, total hardness, odor numbers, and fluoride were also determined on selected samples.

Mineral analysis of two Scioto River samples and one well sample included the following determinations: silica, iron, manganese, calcium, magnesium, sodium, bicarbonate, sulfate, chloride, fluoride, phosphate, total solids and iron and aluminum oxides.

Explanation of Laboratory Tests - An explanation of each analytical determination is given as an aid in interpreting the results of the tests. All determinations, unless otherwise indicated, were performed in accordance with Standard Methods for the Examination of Water and Sewage, Ninth Edition, 1946, of the American Public Health Association (12).

Temperature - Temperature is important, and sometimes critical, for many uses of waters. It affects the palatability of waters, treatment processes, the value of waters for many industrial uses, including cooling processes, and its suitability as a habitat for aquatic life. Temperature of waters controls the solubility of oxygen and thus the saturation level of dissolved oxygen in the stream. Increased temperature may stimulate growth of taste and odor producing organisms.

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Cincinnati, Ohio

TABLE 5
SCIOTO RIVER STUDIES
SUMMARY OF INDIVIDUAL RESULTS - SANITARY EXA
7 DAY CONSECUTIVE SAMPLING PERIOD

Sample Station	Date 1953	Time	Flow	Temp.	Dissolved Oxygen		B.O.D. 5-day 20°C.	Nitrogen			Color	Turbidity	Suspended Solids		Odor Number
								NH_3-N	NO_2-N	NO_3-N			Tot.	Vol.	
			cfs	°C.	ppm	Sat. %	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	
S-76.2	9/23	0600	184	17	0.45	4.6	4.0	19.0	0.004	0.16	125	15	7.6	5.4	-
	9/24	0550	184	17	0.78	8.0	3.9	3.0	0.010	0.10	100	20	7.8	4.0	-
	9/25	0600	177	18	0.58	6.1	4.8	3.5	0.007	0.10	138	15	8.0	7.6	-
	9/26	0555	177	19	0.53	5.6	4.8	4.1	0.007	0.60	113	15	10	7.6	-
	9/27	0605	177	19	0.75	8.0	4.4	5.2	0.010	0.10	113	10	8.0	8.0	-
	9/28	0555	170	19	1.1	12	6.2	7.0	0.014	0.25	125	15	10	10	-
	9/29	0705	170	18	1.0	10	4.5	6.0	<0.001	2.5	113	15	11	7.0	-
Average			177	18	0.74	7.8	4.7	6.8	0.007	0.54	117	15	8.9	7.1	-
S-54.9 (Higby Bridge)	9/23	0700	285	18	0	0	6.3	13	0.025	0.16	88	25	11	7.0	-
	9/24	0550	283	18	0	0	8.5	2.5	<0.001	0.10	88	33	16	8.5	-
	9/25	0650	281	18	0	0	8.8	1.9	<0.001	0.10	88	29	12	8.8	-
	9/26	0625	279	20	0	0	4.7	3.1	<0.001	0.05	88	28	14	12	-
	9/27	0655	279	19	0	0	12	2.4	<0.001	0.30	100	34	12	10	-
	9/28	0630	273	20	0	0	13	2.2	<0.001	0.10	88	33	14	12	-
	9/29	0750	271	18	0	0	10	1.4	0.0013	0.40	88	33	14	10	-
Average			279	19	0	0	9.1	3.8	0.004	0.17	90	31	13	9.8	-
S-45.0 (Omega Bridge)	9/23	0735	318	17	2.8	29	4.6	3.1	0.007	0.16	75	25	16	9.2	-
	9/24	0625	316	17	3.7	38	3.8	2.5	0.034	0.10	63	25	18	4.4	-
	9/25	0655	314	18	3.3	35	5.4	1.9	0.034	0.14	88	20	16	9.2	-
	9/26	0640	312	19	2.3	25	4.4	1.9	0.035	0.10	63	20	12	8.0	-
	9/27	0700	312	19	2.5	27	2.9	1.2	0.035	0.30	63	15	9.2	8.8	-
	9/28	0715	305	18	2.3	24	6.3	2.3	0.035	0.10	75	20	16	9.6	-
	9/29	0815	303	18	1.2	13	5.9	2.1	0.017	0.30	88	20	13	11	-
Average			312	18	2.6	27	4.8	2.1	0.028	0.17	74	21	14	8.6	-
S-34.0 (At AEC Water Intake)	9/23	0745	325	18	11	115	7.2	1.6	<0.001	0.16	75	190	48	22	32
	9/24	0650	323	17	6.9	71	4.9	0.1	0.050	0.20	75	42	26	9.2	80
	9/25	0620	321	18	6.7	70	4.0	0.5	0.040	1.0	60	35	24	10	12
	9/26	0550	319	19	5.6	60	5.4	1.1	0.11	2.0	63	35	22	7.2	96
	9/27	0620	319	19	5.8	62	5.6	0.6	0.11	1.0	63	31	21	11	160
	9/28	0635	311	18	6.8	72	7.2	0.9	0.11	0.50	50	41	23	12	256
	9/29	0900	309	18	7.2	75	5.6	0.8	0.14	2.0	63	43	20	11	96
Average			318	18	7.2	75	5.7	0.8	0.008	0.98	64	60	26	12	-

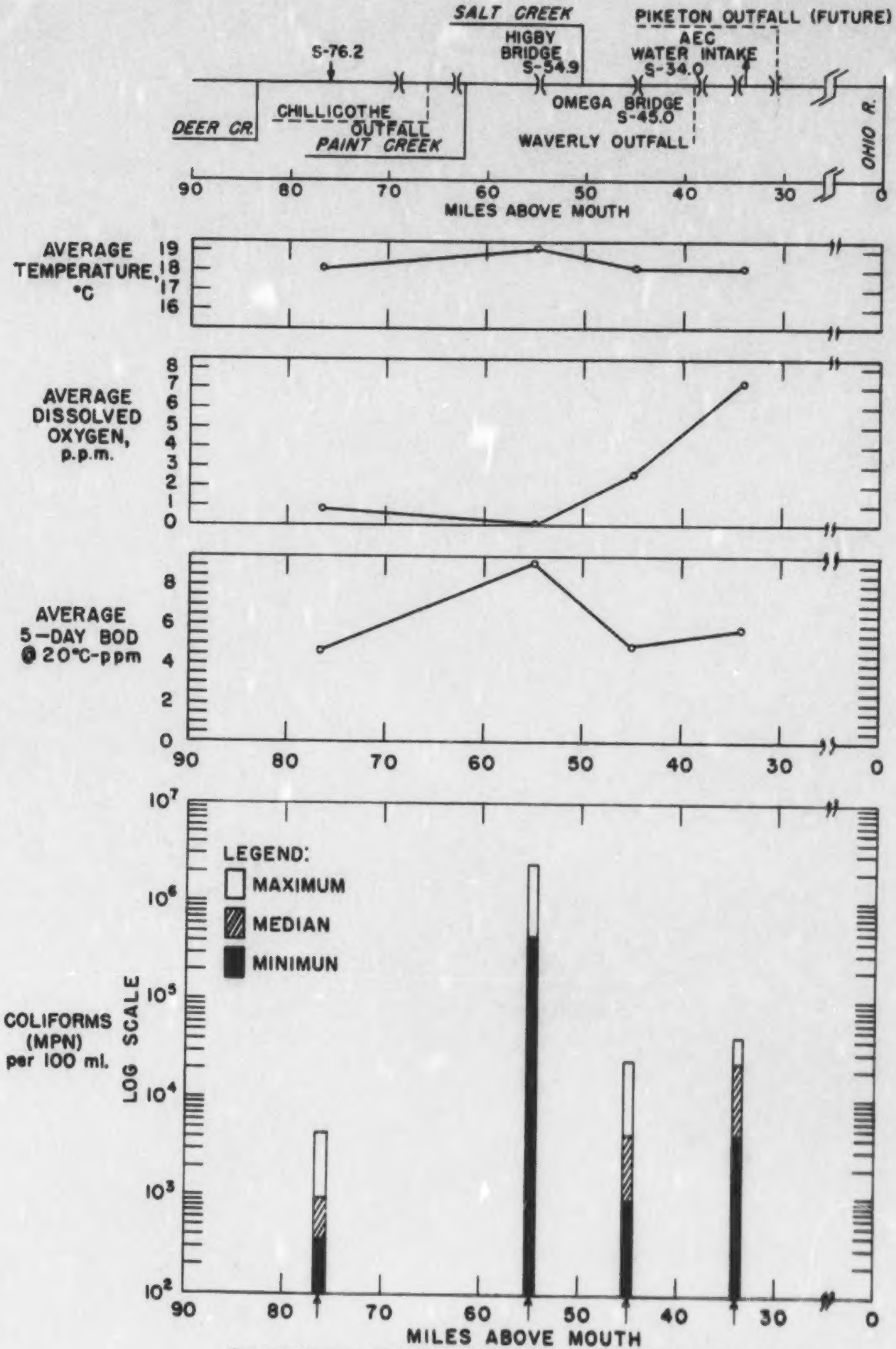
* Median value instead of average value.

Note: Flows at S-45.0 and S-34.0 were estimated on the basis of the discharg

TABLE 5
SCIOTO RIVER STUDIES
OF INDIVIDUAL RESULTS - SANITARY EXAMINATIONS
7 DAY CONSECUTIVE SAMPLING PERIOD

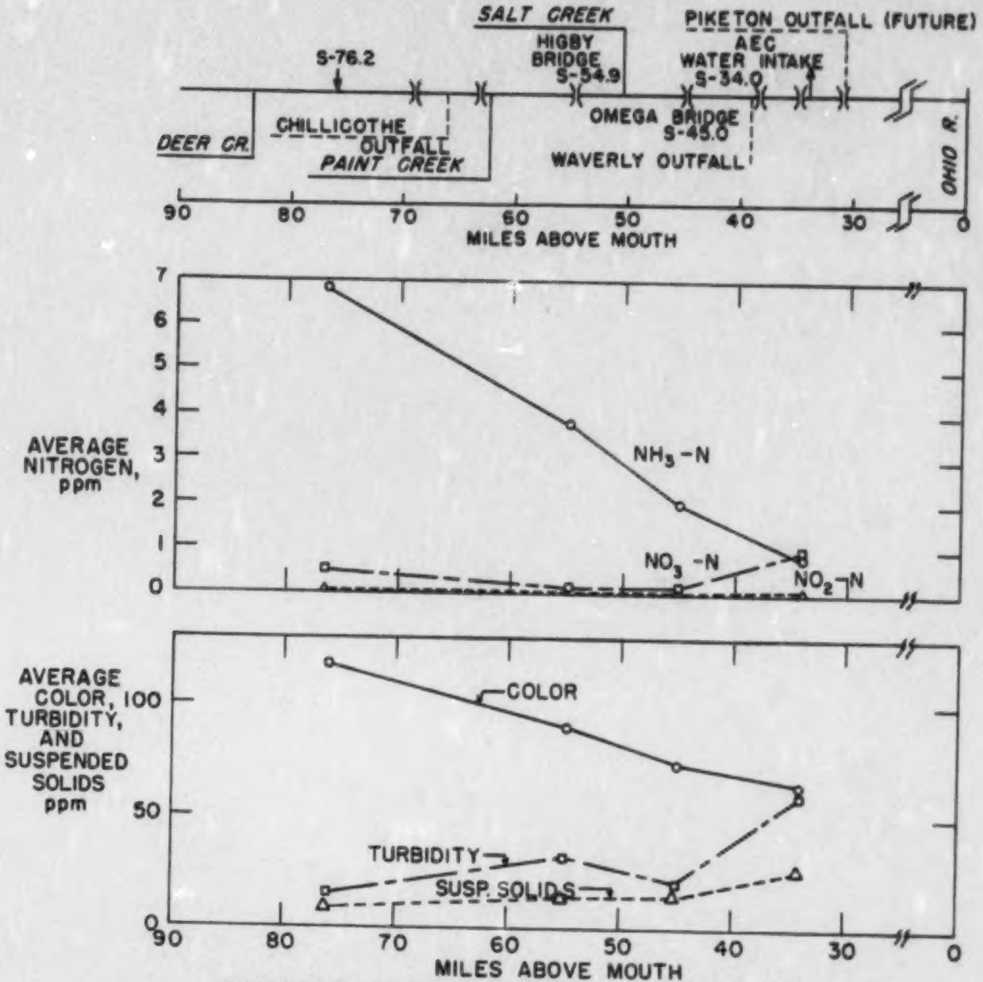
ogen		Color	Turbidity	Suspended Solids		Odor Number	Fluoride	Chloride	Total Hardness as CaCO$_3$	pH	Total Alkalinity as CaCO$_3$	Coliform Bacteria	Total Bacteria (37°C; Agar)
$_2$-N	NO$_3$-N			Tot.	Vol.		F$^-$	Cl$^-$					
pm	ppm	ppm	ppm	ppm	ppm		ppm	ppm	ppm		ppm	MPN per 100 ml.	per ml.
004	0.16	125	15	7.6	5.4	-	-	-	-	7.8	310	360	4,000
010	0.10	100	20	7.8	4.0	-	-	-	-	7.7	289	930	2,400
.007	0.10	138	15	8.0	7.6	-	-	-	-	7.8	299	4,300	43,000
007	0.60	113	15	10	7.6	-	-	-	-	7.8	304	930	3,500
010	0.10	113	10	8.0	8.0	-	2.9	-	-	7.6	294	930	4,500
014	0.25	125	15	10	10	-	-	-	338	7.8	301	1,500	14,000
001	2.5	113	15	11	7.0	-	-	47	-	7.7	305	4,300	2,800
007	0.54	117	15	8.9	7.1	-	-	-	-	-	301	930*	4,000*
.025	0.16	88	25	11	7.0	-	-	-	-	7.8	302	1,100,000	560,000
.001	0.10	88	33	16	8.5	-	-	-	-	7.7	290	430,000	1,210,000
.001	0.10	88	29	12	8.8	-	-	-	-	7.8	292	430,000	1,460,000
.001	0.05	88	28	14	12	-	-	-	-	7.7	302	2,400,000	425,000
.001	0.30	100	34	12	10	-	1.5	-	-	7.6	298	430,000	5,350,000
.001	0.10	88	33	14	12	-	-	-	333	7.7	283	750,000	9,100,000
.0013	0.40	88	33	14	10	-	-	46	-	7.6	293	430,000	7,350,000
.004	0.17	90	31	13	9.8	-	-	-	-	-	294	430,000*	1,210,000*
.007	0.16	75	25	16	9.2	-	-	-	-	7.8	291	2,300	75,000
.034	0.10	63	25	18	4.4	-	-	-	-	7.8	290	4,300	7,200
.034	0.14	88	20	16	9.2	-	-	-	-	7.9	295	24,000	8,300
.035	0.10	63	20	12	8.0	-	-	-	-	7.8	294	4,300	3,000
.035	0.30	63	15	9.2	8.8	-	-	-	-	7.7	287	930	4,000
.035	0.10	75	20	16	9.6	-	-	-	340	7.7	271	4,300	15,000
.017	0.30	88	20	13	11	-	-	46	-	7.7	304	24,000	123,000
.028	0.17	74	21	14	8.6	-	-	-	-	-	290	4,300*	8,300*
.001	0.16	75	190	48	22	32	-	-	-	8.4	302	43,000	10,000
.050	0.20	75	42	26	9.2	80	-	-	-	8.0	294	9,300	3,700
.040	1.0	60	35	24	10	12	-	-	-	8.0	294	43,000	1,100
.11	2.0	63	35	22	7.2	96	-	-	-	8.0	296	21,000	520
.11	1.0	63	31	21	11	160	-	-	-	8.0	283	23,000	1,900
.11	0.50	50	41	23	12	256	-	-	336	8.0	298	23,000	3,000
.14	2.0	63	43	20	11	96	-	46	-	7.9	295	43,000	1,300
.008	0.98	64	60	26	12	-	-	-	-	-	295	23,000*	1,900*

estimated on the basis of the discharge at S-54.9 (Higby Bridge).



SANITARY EXAMINATION – SEPTEMBER 1953
7-DAY CONSECUTIVE SAMPLING PERIOD
SCIOTO RIVER STUDIES

FIGURE 8



SANITARY EXAMINATION – SEPTEMBER 1953
7-DAY CONSECUTIVE SAMPLING PERIOD
SCIOTO RIVER STUDIES

FIGURE 8 (CONT'D)

TABLE 6
SCIOTO RIVER STUDIES
RESULTS OF CHLORINATION STUDIES
A.E.C. - WATER INTAKE

FREE RESIDUAL CHLORINE

9/25
20° C., 30 min.

Chlorine Added	Chlorine Residual
2.05 ppm	1.17 ppm
4.10	2.60
8.20	1.57
12.3	3.16
16.4	6.59
20.5	10.5
22.6	12.7
24.6	14.6
26.7	16.3
28.7	18.3
30.8	20.4
32.8	22.3

9/26
22° C., 30 min.

Chlorine Added	Chlorine Residual
1.92 ppm	1.42 ppm
3.83	2.80
5.75	4.08
7.66	5.46
9.58	5.24
11.5	2.47
15.3	2.59
19.2	5.93
21.1	7.43
23.0	9.10
24.9	10.8
26.8	12.7
28.7	14.5
30.6	16.3

9/27
22° C., 30 min.

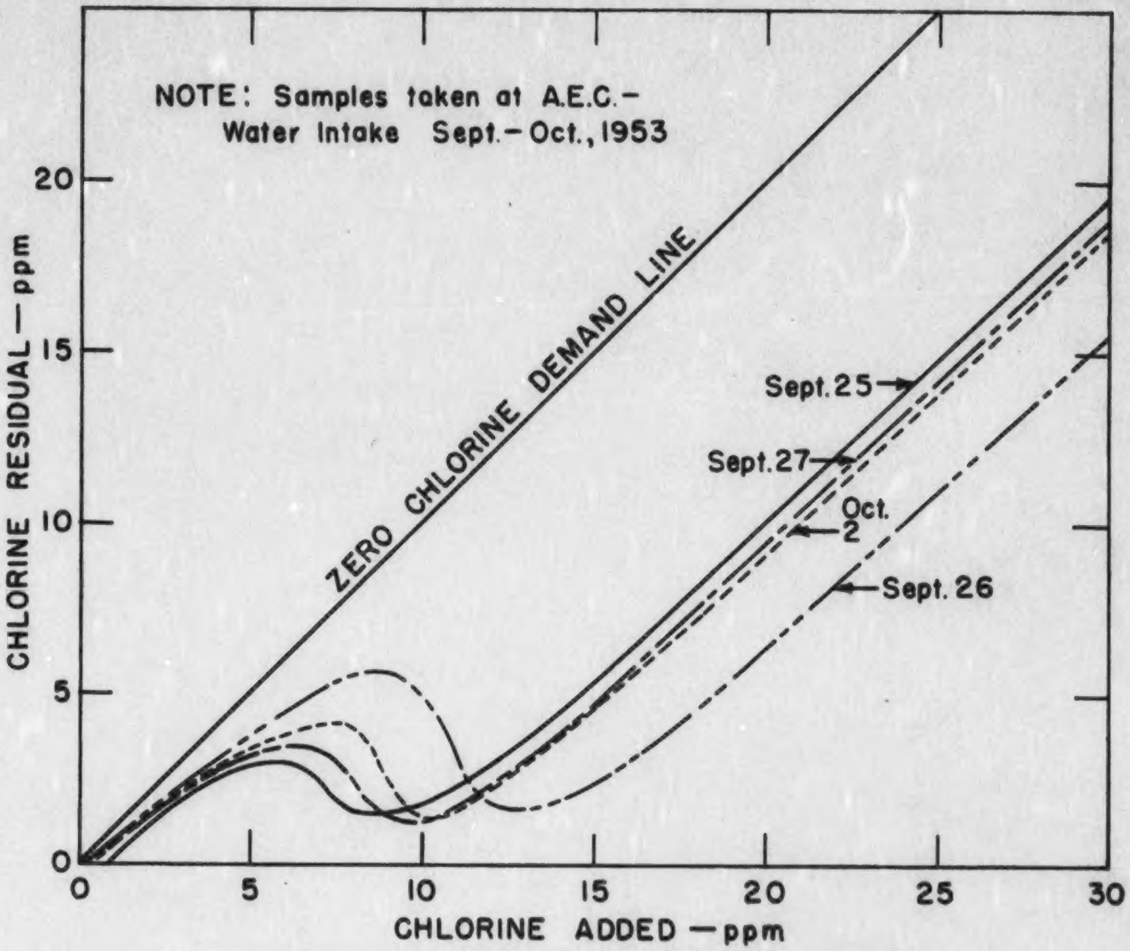
Chlorine Added	Chlorine Residual
1.68 ppm	1.15 ppm
3.35	2.31
5.03	3.28
6.70	3.46
8.38	2.09
9.38	1.22
10.1	1.23
11.1	1.76
11.7	2.22
13.4	3.32
15.1	4.74
16.8	6.24
20.1	9.50
23.4	12.6

10/2 (24 hr. comp.)
15° C., 30 min.

Chlorine Added	Chlorine Residual
1.30 ppm	0.67 ppm
2.59	1.75
3.89	2.83
5.18	3.44
6.48	3.99
7.25	4.18
7.77	4.15
8.55	3.18
9.07	2.88
10.4	1.31
13.0	2.85
15.5	5.09
18.1	7.30
20.7	9.83

CHLORINE DEMAND

Date 1953	Temp. °C.	Contact Time min.	Chlorine Demand ppm
9/28	26	10	0.74
9/29	18	10	0.72
10/2 24 hr. comp.	15	10	0.54



DATE	TEMP. °C.	pH	TIME OF CONTACT
SEPT. 25	20	8.0	30 MIN.
SEPT. 26	22	8.0	30 MIN.
SEPT. 27	22	8.0	30 MIN.
OCT. 2	15	8.2	30 MIN.

CHLORINATION STUDIES
SCIOTO RIVER STUDIES

FIGURE 9

Environmental Health Center
U. S. Public Health Service
Cincinnati, Ohio

TABLE 7
SCIOTO RIVER STUDIES
SUMMARY OF INDIVIDUAL RESULTS - SANITARY EXAMINATIONS
24 HOUR SAMPLING PERIOD
September 30, 1953

Time	Flow	Temp.	Dissolved Oxygen		B.O.D. 5-day 20°C.	Nitrogen			Color	Tur-bid-ity	Suspended Solids		Odor Num-ber	Fluo-ride
						NH_3-N	NO_2-N	NO_3-N			Tot.	Vol.		F^-
	cfs	°C.	ppm	Sat. %	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm		ppm
									S-34.0: AEC WATER INTAKE					
0000	302*	19	6.7	72	7.2	0.70	0.16	1.9	63	33	14	9.2	96	-
0200		19	6.2	66	7.4	0.85	0.16	2.0	-	-	-	-	-	-
0400		19	5.9	63	5.6	0.85	0.15	2.0	-	-	-	-	-	-
0600		19	5.5	59	7.0	0.95	0.15	2.2	63	34	16	9.2	-	1.74
0800		19	5.8	62	7.1	0.95	0.15	2.3	-	-	-	-	-	-
1000		19	6.2	66	8.2	0.77	0.17	2.5	-	-	-	-	-	-
1200		20	8.7	95	7.3	0.90	0.18	2.5	63	38	17	12	64	-
1400		22	10.6	120	7.4	0.77	0.15	2.3	-	-	-	-	-	-
1600		23	11.7	135	8.1	0.77	0.15	2.5	-	-	-	-	-	-
1800		22	11.3	128	8.6	0.85	0.15	2.5	63	37	17	13	-	-
2000		22	10.1	114	8.0	0.85	0.15	2.5	-	-	-	-	-	-
2200		21	8.5	94	7.3	-	0.14	2.5	-	-	-	-	-	-
2400		20	7.4	81	7.0	-	0.17	2.5	63	37	17	9.6	96	-
Average		20	8.0	89	7.4	0.84	0.16	2.3	63	36	16	11	-	-
Maximum		23	11.7	135	8.6	0.95	0.18	2.5	63	38	17	13	96	-
Minimum		19	5.5	59	5.6	0.70	0.14	1.9	63	33	14	9.2	64	-

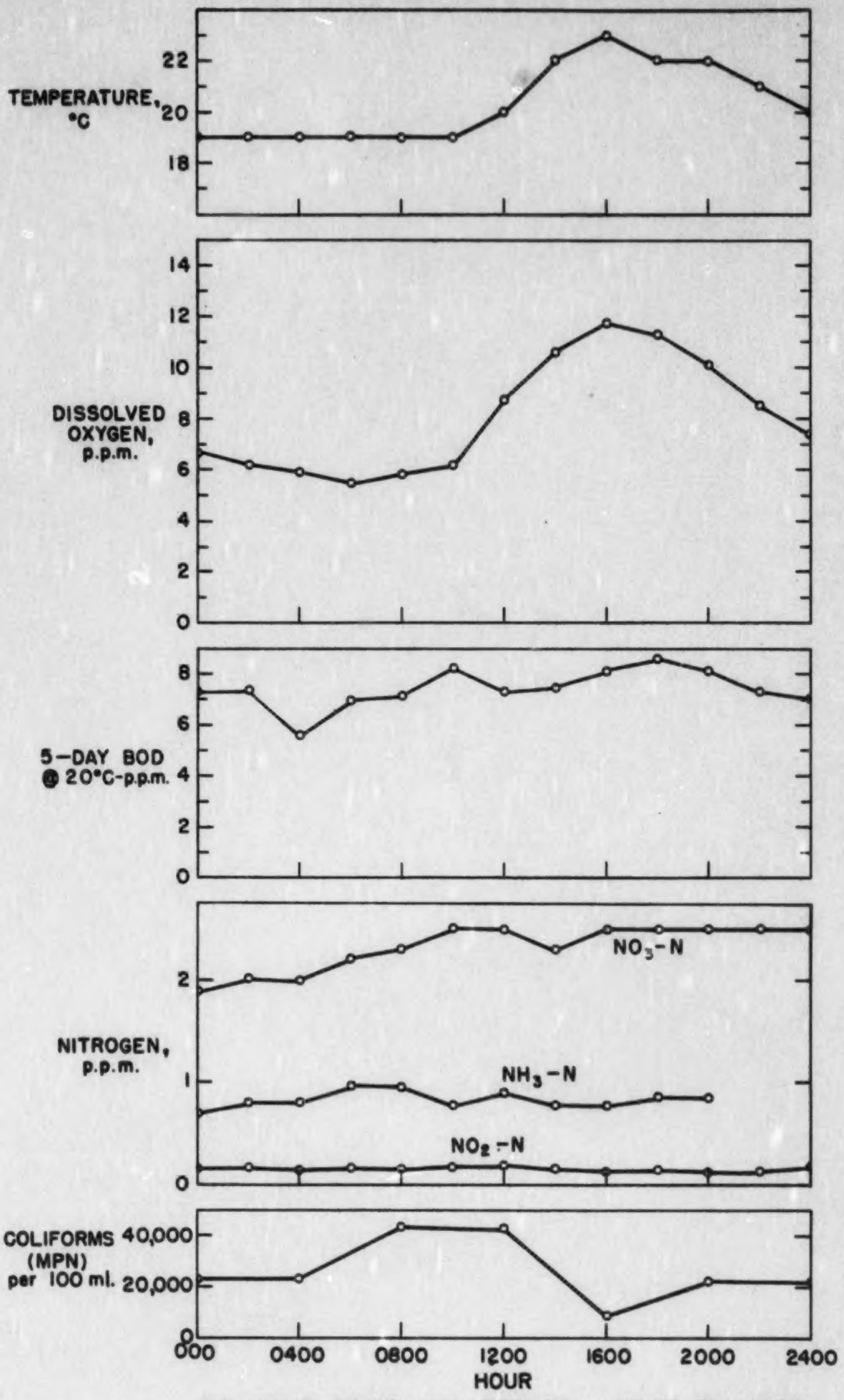
* Estimated on the basis of the discharge at S-54.9 (Higby Bridge Gage).

** Median value instead

TABLE 7
SCIOTO RIVER STUDIES
OF INDIVIDUAL RESULTS - SANITARY EXAMINATIONS
24 HOUR SAMPLING PERIOD
September 30, 1953

	Color	Turbidity	Suspended Solids		Odor Number	Fluoride	Chloride	Total Hardness as $CaCO_3$	pH	Total Alkalinity as $CaCO_3$	Coliform Bacteria	Total Bacteria (37°C; Agar)
NO_3-N ppm	ppm	ppm	Tot. ppm	Vol. ppm		F^- ppm	Cl^- ppm	ppm		ppm	MPN per 100 ml.	per ml.
S-34.0: AEC WATER INTAKE												
1.9	63	33	14	9.2	96	-	44	340	8.0	296	23,000	2,800
2.0	-	-	-	-	-	-	-	-	7.9	295	-	-
2.0	-	-	-	-	-	-	44	-	7.9	293	23,000	3,900
2.2	63	34	16	9.2	-	1.74	-	346	7.8	297	-	-
2.3	-	-	-	-	-	-	43	-	7.9	298	43,000	5,200
2.5	-	-	-	-	-	-	-	-	8.0	294	-	-
2.5	63	38	17	12	64	-	43	346	8.0	294	43,000	8,200
2.3	-	-	-	-	-	-	-	-	8.2	296	-	-
2.5	-	-	-	-	-	-	42	-	8.2	294	9,300	2,100
2.5	63	37	17	13	-	-	-	339	8.2	290	-	-
2.5	-	-	-	-	-	-	42	-	8.2	284	23,000	2,500
2.5	-	-	-	-	-	-	-	-	8.1	287	-	-
2.5	63	37	17	9.6	96	-	42	342	8.2	290	23,000	3,250
2.3	63	36	16	11	-	-	43	343	-	293	23,000**	3,250**
2.5	63	38	17	13	96	-	44	346	8.2	298	43,000	8,200
1.9	63	33	14	9.2	64	-	42	339	7.8	284	9,300	2,100

** Median value instead of average value.



24 HOUR SAMPLING PERIOD — SEPT. 30, 1953
STATION S—34.0 (A.E.C.-WATER INTAKE)
SCIOTO RIVER STUDIES

FIGURE 10

Environmental Health Center
U. S. Public Health Service
Cincinnati, Ohio

TABLE 8
SCIOTO RIVER STUDIES
COMPILATION OF MINERAL ANALYSES DA
RESULTS IN PPM*

Source	Scioto R. S-34.0 At AEC Water Intake (1)	Scioto R. S-34.0 At AEC Water Intake (1)	AEC Wells (1)	AEC Wells (2)	Peepee Twp. Well #16 Waverly (3)	Scioto R. near Circlevil (3)
Date	9/24/53	9/30-10/1	10/6/53	9/7/53	4/29/52	4/30/46
Time	1530	24 hr. comp.	1445	-	-	-
Discharge cfs	283(4)	264(4)	-	-	-	439
Color	-	65	-	0	-	8
pH	-	8.2	-	7.2	7.5	7.4
Silica SiO_2	6.3	10.8	9.9	9.0	7	1.6
Iron (Fe)	0.005	0.005	0.44	1.9	1.04	0.04
Manganese (Mn)	<0.013	<0.013	0.13	0.26	-	-
Calcium (Ca^{++})	87	86	85	76	92	85
Magnesium (Mg^{++})	28	31	29	34	27	29
Sodium (Na^+)	8.9	18	2.3	4.4	-	22(5)
Bicarb. (HCO_3^-)	337	333	354	348	312	246
Sulfate (SO_4^{--})	105	120	51	48	-	129
Chloride (Cl^-)	41	43	6.7	3.8	14	22
Fluoride (F^-)	-	1.6	0.06	0	0.05	1.8
Nitrate (N)	0.2	2.5	0.09	0.3(6)	-	8.4(
Phosphate (PO_4^{---})	2.5	2.5	<0.01	-	-	-
Dissolved Solids	545	561	395	348	437	455
Suspended Solids	45	18	1.8	-	-	-
Vol.Susp.Solids	24	12	1.4	-	-	-
Hardness as $CaCO_3$						
Total	333	334	329	328	342	331
Carbonate	276	273	290	285	256	201
Non-carbonate	57	61	39	43	86	130

(1) Analyses by U. S. Public Health Service
(2) Analyses by U. S. Geological Survey
(3) Analyses by Ohio Dept. of Health, & Ohio Dept. of Natural Resources
(4)
(5)
(6)

* pH excepted

TABLE 8
SCIOTO RIVER STUDIES
COMPILATION OF MINERAL ANALYSES DATA
RESULTS IN PPM*

AEC Wells (1)	AEC Wells (2)	Beepee Twp. Well #16 Waverly (3)	Scioto R. near Circleville (3)	Scioto R. near Circleville (3)	Scioto R. at Chillicothe (3)	Scioto R. at Higby (3)	Scioto R. at Higby (3)
10/6/53	9/7/53	4/29/52	4/30/46	9/3/46	10/31/49	5/3/46	9/3/46
1445	-	-	-	-	-	-	-
-	-	-	439	180	330	1470	548
-	0	-	8	12	53	15	8
-	7.2	7.5	7.4	7.6	7.5	7.7	7.6
9.9	9.0	7	1.6	5.2	5.0	3.4	4.4
0.44	1.9	1.04	0.04	0.06	0.10	0.02	0.03
0.13	0.26	-	-	-	-	-	-
85	76	92	85	96	85	70	80
29	34	27	29	32	32	28	31
2.3	4.4	-	22(5)	38(5)	38(5)	15(5)	19(5)
354	348	312	246	268	295	265	296
51	48	-	129	168	130	80	96
6.7	3.8	14	22	34	24	13	14
0.06	0	0.05	1.8	2.8	2.6	0.5	1.4
0.09	0.3(6)	-	8.4(6)	5.0(6)	11.0(6)	3.4(6)	3.0(6)
<0.01	-	-	-	-	-	-	-
395	348	437	455	547	479	352	417
1.8	-	-	-	-	-	-	-
1.4	-	-	-	-	-	-	-
329	328	342	331	371	344	290	327
290	285	256	201	219	242	217	243
39	43	86	130	152	102	73	84

ice

Ohio Dept. of Natural Resources

(4) Discharge at Highby
(5) Value for sodium and potassium
(6) Value expressed as NO_3

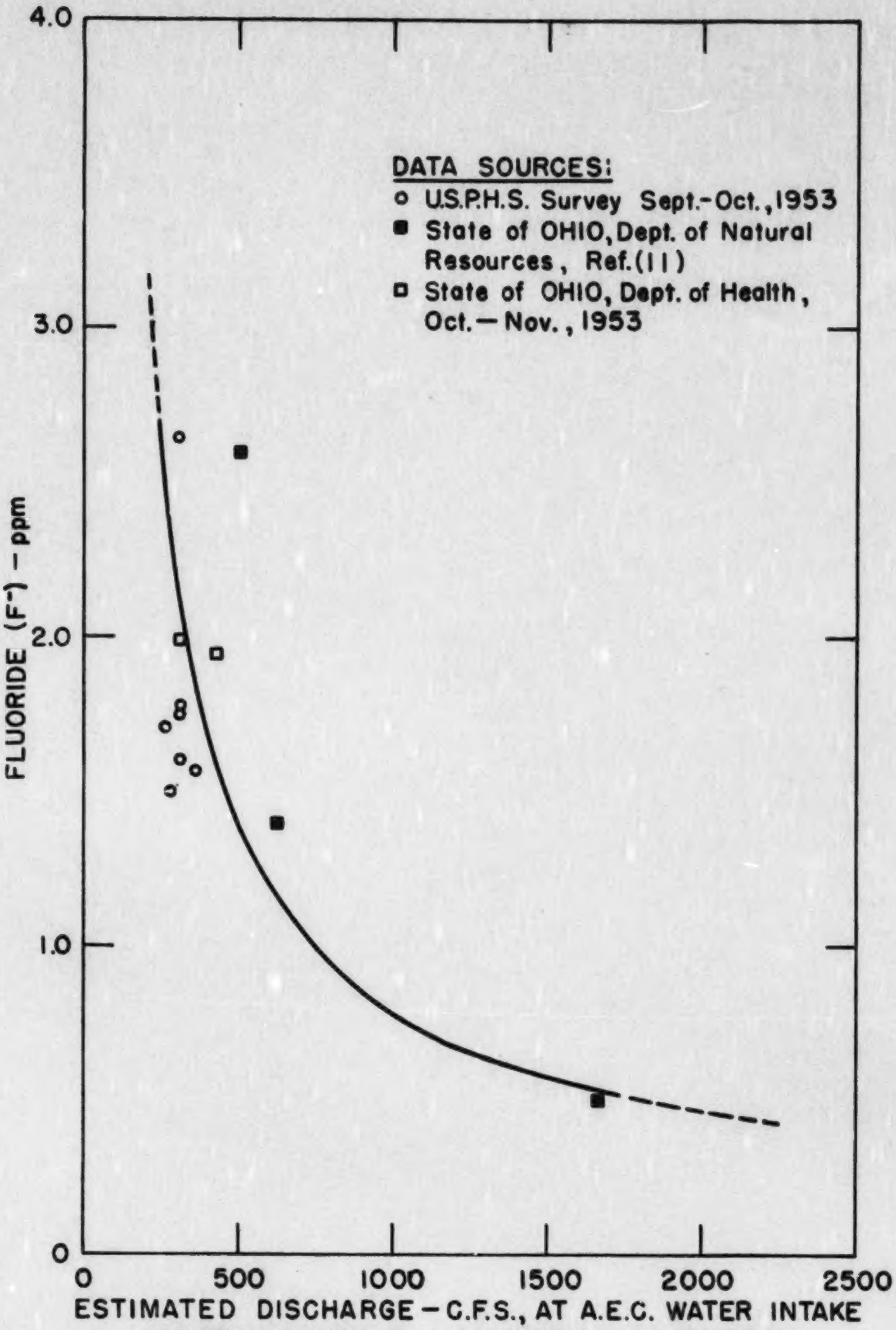
Environmental Health Center
U. S. Public Health Service
Cincinnati, Ohio

TABLE 9
SCIOTO RIVER STUDIES
SUMMARY OF MISCELLANEOUS DETERMINATI
SEPTEMBER-DECEMBER, 1953

Sample Station	Date 1953	Time	Flow cfs	Temp. °C.	Dissolved Oxygen		B.O.D. 5-day, 20°C ppm	Fluorid F^- ppm
					ppm	% Sat.		
S-34.0 (AEC-Water Intake)	9/23				10.2			
	9/22	1010	333	(19)	12.0	(128)		
		1340		19.5	17.2	186		
		1555		20	18.9	206		
		1640		20	19.4	211		
	9/26	0455	318	(18)	5.6	(59)		
		0514		(18)	5.6	(59)		
		0530		18	5.7	60		
		0555		19	5.6	60		
		0605		18	5.5	58		
		0617		(19)	5.4	(58)		
		1030		19	6.4	68		
		1130		21	7.1	79		
		1400		21	8.6	96		
	10/8	0950	309	-	-	-	-	2.6
	11/11	1500	306	-	-	-	-	1.8
	12/3	-	-	-	-	-	-	1.9
S-45.0	9/3	1015	-	-	5.0			
S-54.9	9/3	0855	-	-	0.5			
	10/8	1130	271	-	-	-	-	1.6
	11/11	1650	269	-	-	-	-	1.7
S-63.4	9/3	-	-	-	1.4	-		
S-76.9	11/11	1125	-	-	-	-	-	4.0
S-118.1	10/14	1130	-	-	-	-	-	2.01
S-135.	11/11	0955	-	-	-	-	-	0.36
S-50.6, Sa-1.4	10/8	1305	-	15	7.4	73		
S-62.5 Pa-1.5	10/2	1030	-	24	2.4	28	76.7	
S-62.5 Pa-3.1	10/2	0930	-	18	7.6	80		
	10/8	1220	-	-	-	-	-	0.08
S-62.5 Pa-3.0, Ho-0.1	10/2	1007	-	35	1.1	16	188	
	10/8	1215	-	-	-	-	-	0.2
S-83.3, De-0.6	10/14	930	-	-	-	-	-	0.66
S-99.6, Da-3.0	10/14	1000	-	-	-	-	-	0.50
S-104.2, Wa-1.1	10/21	1130	-	-	-	-	-	0.42
S-115.3, Bi-1.6	10/14	1100	-	-	-	-	-	0.30
AEC Wells	10/6	1445	-	-	-	-	-	-
	10/7	1030	-	-	-	-	-	-
	10/9	0940	-	-	-	-	-	-
	12/3	-	-	-	-	-	-	0.13

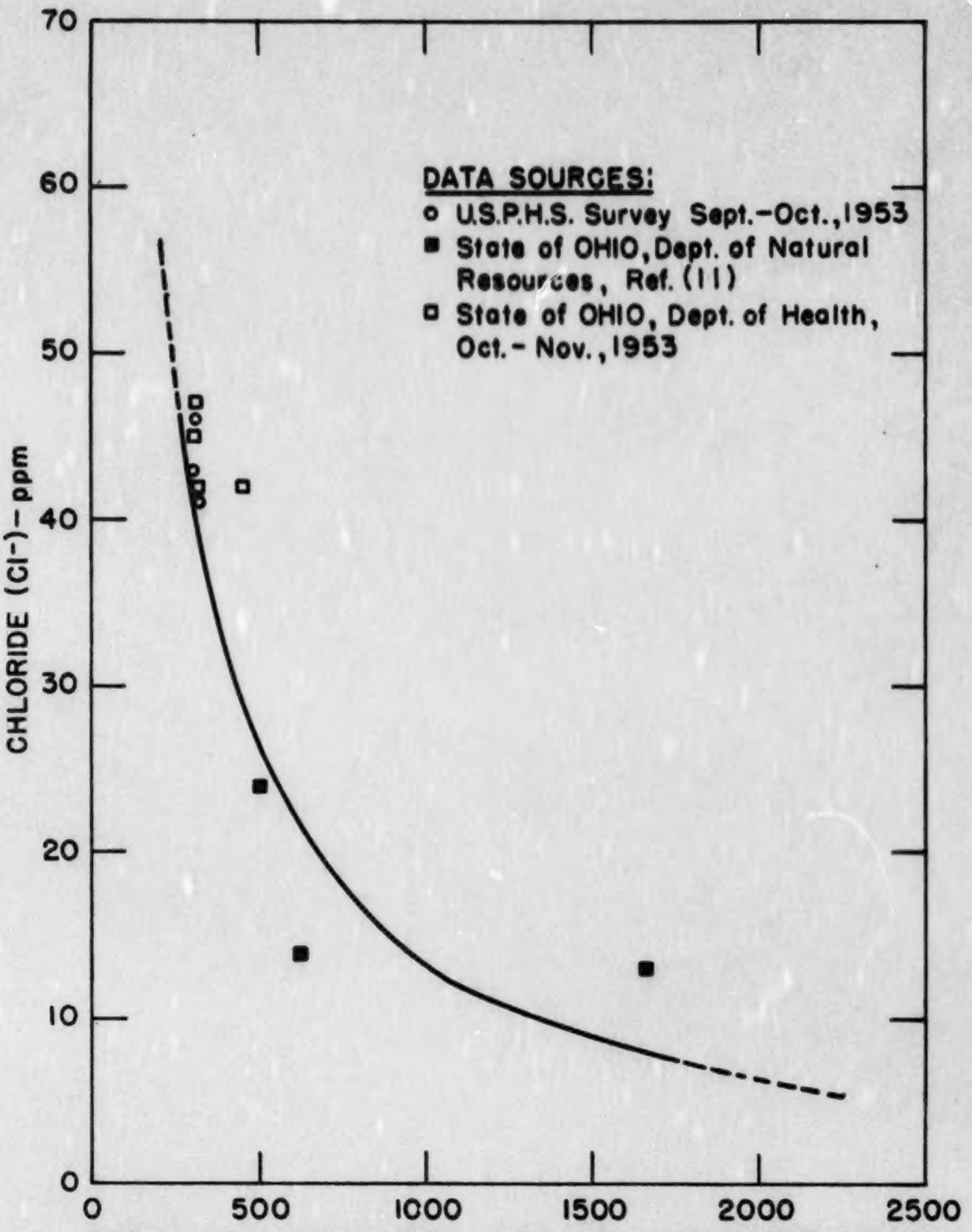
TABLE 9
SCIOTO RIVER STUDIES
SUMMARY OF MISCELLANEOUS DETERMINATIONS
SEPTEMBER-DECEMBER, 1953

lved Oxygen		B.O.D. 5-day, 20°C ppm	Fluoride F^- ppm	Chloride Cl^- ppm	Total Hardness as $CaCO_3$ ppm	pH	Coliform Bacteria MPN per 100 ml.
	% Sat.						
2							
0	(128)						
2	186						
9	206						
4	211						
6	(59)						
6	(59)						
7	60						
6	60						
5	58						
4	(58)						
4	68						
1	79						
6	96						
-	-	-	2.6				
-	-	-	1.8				
-	-	-	1.9	38.	339		
0							
5							
-	-	-	1.6				
-	-	-	1.7				
4	-						
-	-	-	4.0				
-	-	-	2.01				
-	-	-	0.36				
4	73						
4	28	76.7					
6	80						
-	-	-	0.08				
1	16	188					
-	-	-	0.2				
-	-	-	0.66				
-	-	-	0.50				
-	-	-	0.42				
-	-	-	0.30				
-	-	-	-	-	-	7.4	1.4
-	-	-	-	-	-	7.4	<2.1
-	-	-	-	-	-	-	4.7
-	-	-	0.13	6.5	350		



APPROXIMATE RELATIONSHIP BETWEEN FLUORIDE AND DISCHARGE
SCIOTO RIVER STUDIES

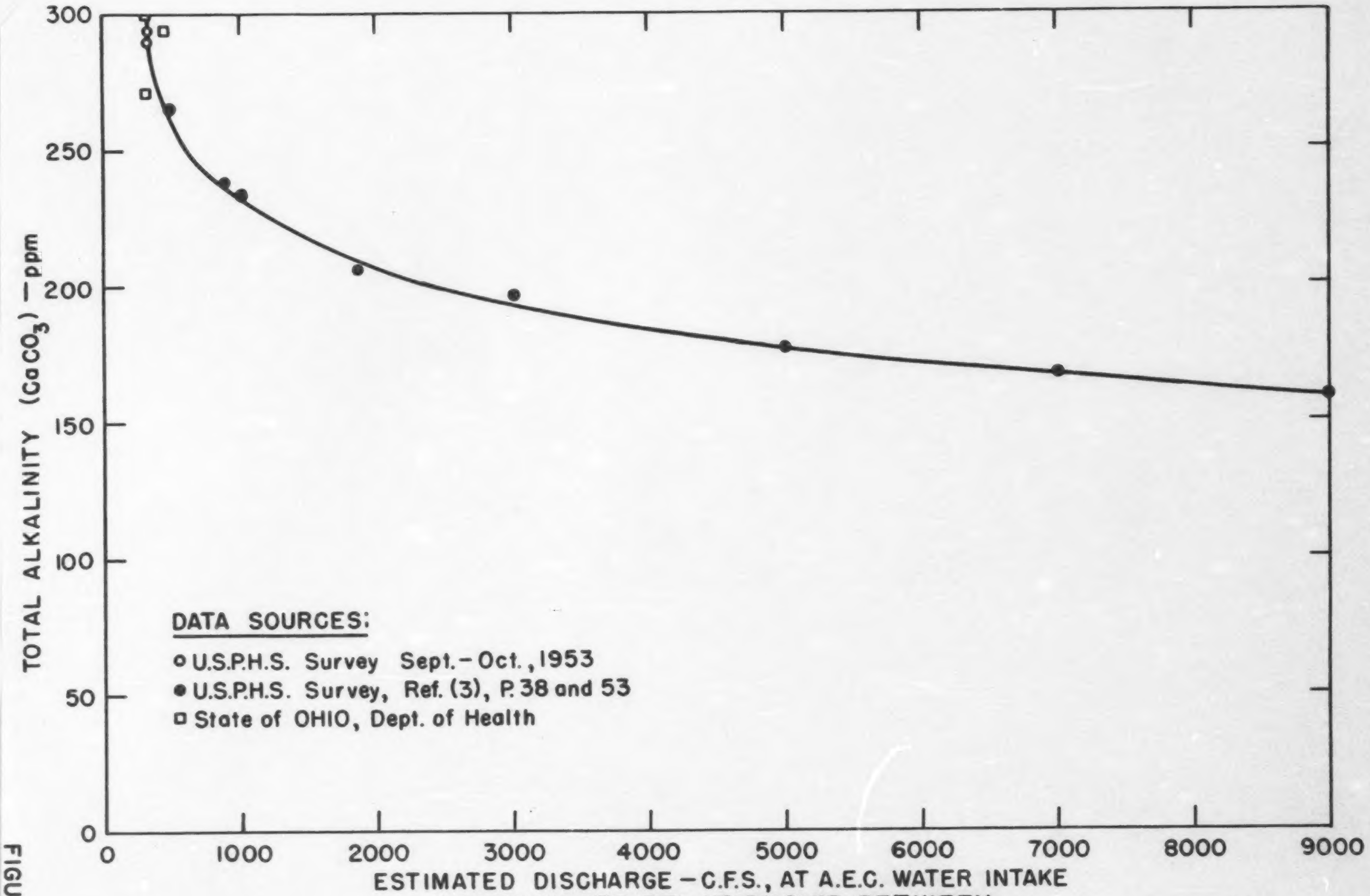
FIGURE 11



APPROXIMATE RELATIONSHIP BETWEEN CHLORIDE AND DISCHARGE

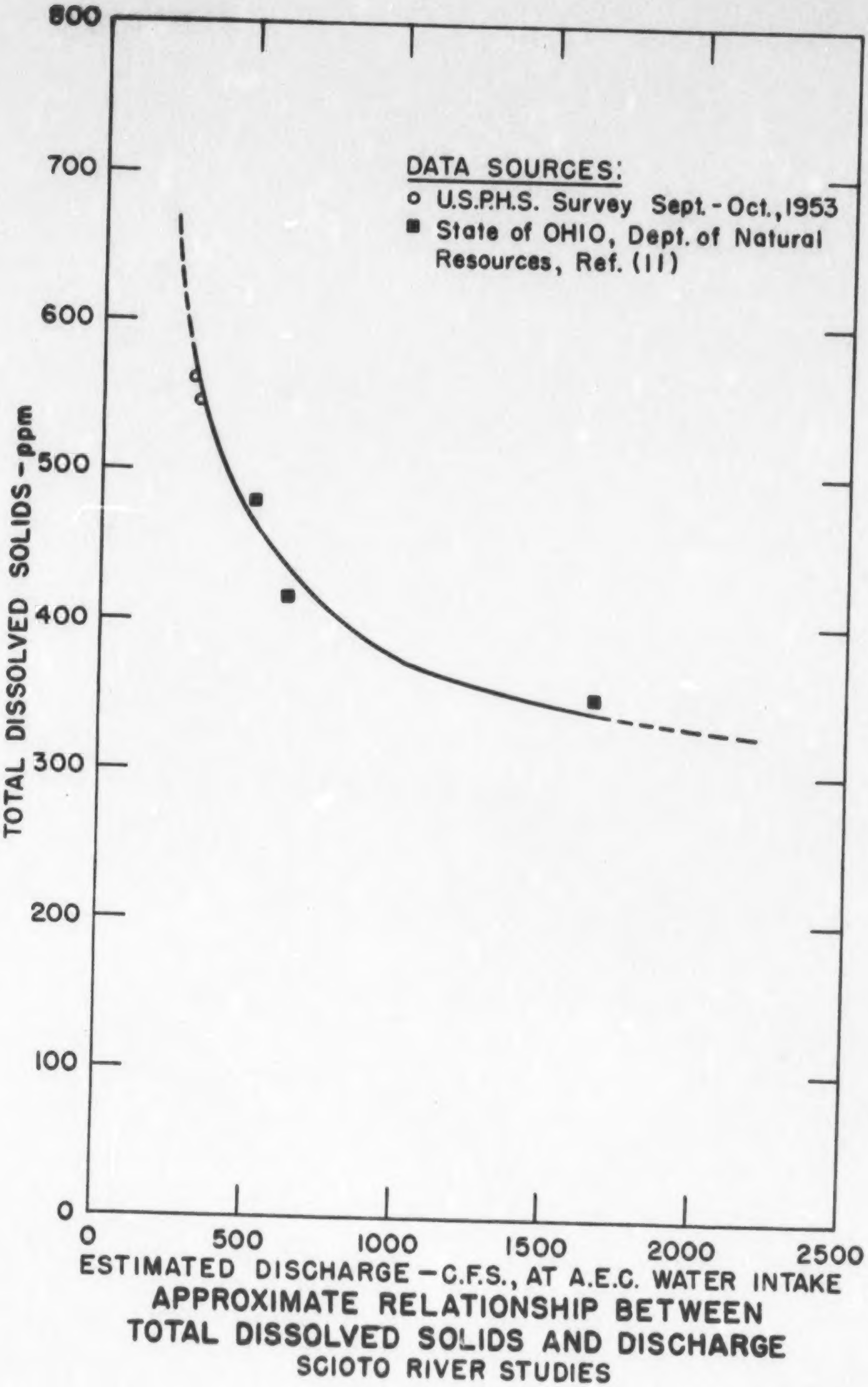
SCIOTO RIVER STUDIES

FIGURE 12



APPROXIMATE RELATIONSHIP BETWEEN
TOTAL ALKALINITY AND DISCHARGE
SCIOTO RIVER STUDIES

FIGURE 13



APPROXIMATE RELATIONSHIP BETWEEN
TOTAL DISSOLVED SOLIDS AND DISCHARGE
SCIOTO RIVER STUDIES

FIGURE 14

Dissolved Oxygen - The content of dissolved oxygen in waters at equilibrium with a normal atmosphere is a function of the temperature and salinity of the waters; the ability of waters to hold oxygen decreases with increase in temperature or dissolved solids. The amount of oxygen dissolved in stream waters is normally limited by the saturation value at various temperatures (11.33 ppm at 10° C. and 9.17 ppm at 20° C.). Natural waters, however, are seldom at equilibrium and seldom exactly saturated with dissolved oxygen, for temperatures are changing and physical, chemical, and biological activities are utilizing or liberating oxygen. The photosynthetic action of some water plants including algae and air entrainment caused by discharging waters over spillways, riffles, etc., may cause "supersaturation." It is necessary that an adequate quantity of dissolved oxygen be present in stream waters to support fish and aquatic life and for natural aerobic purification of waters. Values substantially below the saturation level may indicate the presence of organic pollution.

Biochemical Oxygen Demand - The Biochemical Oxygen Demand (BOD) of polluted waters is the oxygen in parts per million required during stabilization of the decomposable organic matter by aerobic biochemical action. In itself BOD exercises no direct harm. However by depressing the dissolved oxygen content to values that are inimical to fish life and other beneficial uses the BOD influences water quality significantly. Since oxygen solubility decreases and the rate of biochemical oxidation increases with increasing temperature, lowest dissolved oxygen values normally occur during periods of high temperature and low flow.

Ammonia Nitrogen - Although free ammonia is often of vegetable origin and without hygienic significance, its concentration in water in excess of 0.1 ppm renders the water suspect of recent pollution. Ammonia in water will decrease the bactericidal action of chlorine by forming chloramines which are less active than free chlorine.

Nitrite Nitrogen - In waters, nitrite is generally formed by the action of bacteria upon ammonia and organic nitrogen. Under aerobic conditions nitrite is rapidly oxidized to nitrate and when present is indicative of recent pollution.

Nitrate Nitrogen - Nitrate is the end product of the aerobic stabilization of organic nitrogen, and as such it occurs in polluted waters that have undergone self-purification or aerobic treatment processes. Nitrate also occurs in percolating ground waters as a result of the application of fertilizers. Photosynthetic action of algae and water plants is constantly utilizing nitrate and converting it to organic nitrogen in plant cells.

Excessive nitrate, 10-20 ppm or more as N, has been associated with gastrointestinal tract irritation (13), diarrhea, and infant methemoglobinemia (14) (15).

Color - Color in water may be of mineral or organic origin. It may be caused by naturally occuring metallic substances (such as iron compounds), humus material, or algae or by inorganic or organic soluble wastes from many industries. Color in a sample is measured by comparison with the color produced by a solution of platinum and cobalt compounds. The Public

Health Service Drinking Water Standards (2) limit the color of acceptable filtered waters to 20 ppm on the standard platinum-cobalt scale.

Turbidity - The turbidity of waters is attributable to suspended and colloidal matter, the effect of which is to disturb clearness and diminish the penetration of light. No quantitative limits for raw water sources have been established inasmuch as turbidity is usually readily removed by water treatment processes.

Total and Volatile Suspended Solids - In natural waters, suspended solids consist normally of erosion silt, organic detritus and plankton. This is augmented by the discharge of liquid wastes from communities and industries. In raw water sources for domestic use, State agencies generally specify that suspended solids in streams shall not be in sufficient concentration to be objectionable or to interfere with normal treatment processes.

Hydrogen Ion Concentration (pH) - The hydrogen ion concentration is represented by the symbol "pH". The "pH" of a water is the logarithm (base 10) of the reciprocal of the hydrogen ion concentration. It is a measure of intensity rather than quantity. The hydrogen ion concentration of raw water is important in that it affects corrosivity, disinfection and other treatment processes such as coagulation.

Alkalinity - Alkalinity is caused principally by carbonate, bicarbonate, hydroxide, and to a lesser extent by borate, silicate, phosphate, and organic substances. In itself, alkalinity is not considered to be detrimental but when high is generally associated with high hardness and excessive dissolved solids, all of which may be deleterious in various ways depending on water uses.

Coliform Bacteria MPN - The coliform group of organisms includes, by definition, "all aerobic and facultative anaerobic Gram-negative nonsporeforming bacilli which ferment lactose with gas formation" (12). It embraces organisms of diverse origin, among which the best known are (a) Escherichia coli strains, which are usually, but not always, of fecal origin, and (b) intermediate and Aerobacter aerogenes strains, which are usually, but not always, of soil, vegetable, or other nonfecal origin. The numbers of coliform organisms present is expressed in terms of the Most Probable Number (MPN) per 100 ml. of sample. This test gives a good estimate of the sewage pollution of a stream since unpolluted streams generally contain only a small number of coliform organisms.

Total Bacteria - The test for total bacteria enumerates all organisms capable of growing on nutrient agar in 24 hours at 37° C. Plates were inoculated in duplicate in three serial dilutions. Values are expressed in numbers of bacteria per ml. of sample.

In normal surface waters the numbers of organisms present depend in part upon the extent to which the water has been contaminated with decomposing organic matter, either by pollution with sewage or industrial wastes or by contact with the surface of the ground. The bacterial content varies with the extent and nature of the contamination.

Chlorine Demand - The chlorine demand of water is the difference between the amount of chlorine applied and the amount of residual chlorine remaining at the end of the contact period. A high chlorine demand is indicative of a high ammonia, organic matter and other chlorine absorbing materials in the water.

Free Residual Chlorination-("Breakpoint" Chlorination) - Free residual chlorination is the addition of chlorine in sufficient quantities to produce and maintain free available chlorine residuals to the exclusion or near exclusion of combined available chlorine residuals (chloramines). It is chlorination to or beyond the "breakpoint." It is in this respect that it differs from marginal chlorination in which little attention is given to the type of residual produced or its persistancy.

Free residual chlorination is a good disinfection process and in addition can be used to control algal growth, to reduce tastes and odors, to aid coagulation, to oxidize iron and manganese, to bleach colors, and to oxidize ammonia.

The amount of chlorine required to produce free available chlorine residuals depends, among other things, upon the characteristics of the wastes, the time of contact, the temperature, the exposure to sunlight, and the magnitude of the residual desired at any given point in the system. This type of residual can be produced in unpolluted waters, devoid of ammonia, organic matter, hydrogen sulfide, or other reducing material, with chlorine application of 1.0 ppm or less. Grossly polluted waters may require chlorine applications of 20.0 ppm or more.

Once the initial demand has been satisfied the greatest single influence on chlorine requirements to produce free available chlorine residuals is the ammonia content. The ratio of chlorine to ammonia to just reach the point of free available chlorine residual is approximately 10:1, exclusive of the amount of chlorine required to produce the point desired. Ratios as great as 25:1 or more have been encountered in a few instances.

The time required for completion of the free residual chlorination reactions seldom exceeds thirty minutes. The optimum pH values for free residual chlorination are between 6.5 and 8.5.. .

Chloride - Chloride is found in practically all natural waters. It may be of natural mineral origin, from human or animal sewage or from industrial effluents, such as paper works, galvanizing plants, or water softening (zeolite) plants.

Chloride in drinking water is generally not harmful to human beings until high concentrations are reached. Restrictions on chloride concentrations in drinking water are generally based on palatability requirements rather than on health. The Public Health Service Drinking Water Standards of 1946 (2) recommend that chloride not exceed 250 ppm. Excessive chloride increases the soap consuming properties of water and accelerates corrosion in pipes, boilers, and other fixtures. Any sudden increase in the chloride content of a water supply above the normal content should be suspected as a possible indication of pollution from domestic or industrial sources.

Total Hardness - The term "hardness" is applied to the soapneutralizing power of water. Any substance that will form an insoluble curd with soap causes hardness; but since iron, manganese, and other trace elements are seldom present in appreciable concentration in natural waters, hardness is attributable principally to calcium and magnesium ions. Hardness is expressed in terms of calcium carbonate. Statements relating to the desirable limits for hardness in municipal water supplies vary widely. In the Middle West waters having a hardness of less than about 100 ppm are often considered "soft" and quite satisfactory for municipal use.

Odor - Disagreeable odors and tastes in water are associated with the presence of a great variety of substances, particularly living microscopic organisms or decaying vegetation, including weeds, bacteria, fungi, actinomycetes and algae; decaying organic matter; and sewage and industrial waste products.

Odors can be caused by volatile substances in concentrations too small to be detected by ordinary analytical techniques; therefore, reliance must be placed upon the sense of smell. Results are reported in terms of threshold odor numbers, calculated from the amount of sample in the most diluted portion giving perceptible odor. The threshold odor number equals the volume of the dilution divided by the volume of the sample in the dilution. Water free from objectionable odors and tastes are desirable for drinking and domestic uses.

Fluoride - As the most reactive non-metal, fluorine is never found free in nature but is a constituent of sedimentary and igneous rocks.

Fluoride in high concentrations is not ordinarily found in surface waters. Fluoride may be discharged in the wastes from certain industries such as the manufacture of glass and enamels, phosphate fertilizer, or the preserving of wood or mucilages.

The Public Health Service Drinking Water Standards (2) set a limit of 1.5 ppm for fluoride in finished waters. When present in concentrations appreciably higher than 1.5 ppm, fluoride causes mottling of the teeth of children using the water for extended periods of time. The teeth of adults are not affected.

A method developed by Megregian and Solet was used for the determination of fluorides (16) (17).

Sulfate - Sulfate occurs in surface waters as a result of (a) leaching from minerals, (b) final oxidized state of various inorganic sulfur compounds, (c) the oxidized form of sulfur from organic matter and (d) from numerous industrial wastes. The Public Health Service Drinking Water Standards (2) recommend that sulfate not exceed 250 ppm.

Iron - Iron occurs in surface waters as a result of (a) leaching from minerals, (b) corrosion of metallic iron and (c) discharge of iron bearing industrial wastes. Iron generally enters a stream in the ferrous state. It is rapidly oxidized in natural surface waters to the ferric condition and then forms insoluble hydroxides which are either precipitated or remain suspended as a colloid. A well-aerated water seldom contains a high concentration of iron. Ground waters, however, may contain high concentrations of ferrous iron. Even though perfectly clear when first pumped from a well, in a few hours' time oxidation will cause the iron to be precipitated and yield a red or brown color or sediment. Iron is objectionable in a domestic water supply principally because it will stain laundry and plumbing fixtures. High concentrations will cause objectionable taste and turbidity.

The 0.3 ppm limit (2) for iron (and manganese) in domestic water supplies (finished water) is based upon esthetic, economic and taste rather than physiological considerations.

Manganese - Manganese is seldom present in natural waters in concentrations above 1 ppm, and is more common in ground than in surface waters. Manganese frequently accompanies iron in water and the two are grouped together where limits are proposed. Objections to manganese are the same as for iron. Both iron and manganese may interfere with the orthotolidine test for free chlorine. Both iron and manganese are easily removed by conventional water treatment processes.

Phosphate - Phosphate may occur in surface or ground waters (a) as a result of leaching from minerals or agricultural fertilizers, (b) as one of the stabilized products of decomposition of organic matter, (c) as a result of industrial wastes or (d) as a constituent of a water supply that has undergone phosphate treatment. Phosphate in the concentrations usually found in raw water sources has no physiological significance; it does, however, tend to encourage excessive growth of algae. The latter condition is likely to occur when the concentration of inorganic phosphorous is over 0.01 ppm.

Calcium - Calcium salts are dissolved from practically all rocks, but especially from limestone, dolomite and gypsum. Calcium and magnesium are the principal ions causing hard water and are largely responsible for the formation of boiler scale.

Magnesium - Magnesium salts and ions are commonly found in most natural waters, particularly in hard water areas. Magnesium is considered relatively non-toxic to man in moderate concentrations and limits in drinking water are imposed because of the taste produced by magnesium salts. At high concentrations magnesium salts have a laxative effect, particularly upon new users. The Public Health Service recommends a limit of 125 ppm (2).

Silica - The element, silicon, is not found free in nature but occurs as silica in sand or quartz and as silicates in some minerals. Silicon dioxide or silica is insoluble in water but may occur in natural waters as finely divided or colloidal suspended matter or in the form of silicates. Silica affects the usefulness of water since it contributes to the formation of scale particularly in boilers.

Bicarbonate - Bicarbonate occurs in natural waters largely through the action of carbon dioxide which enables the water to dissolve the carbonates of calcium and magnesium from limestone. Other than the fact that excessive bicarbonate adds to the salinity and total solids content of the water, and, through the complex operations of the carbonate equilibria, tends to form (along with calcium, etc.) carbonate scale at high temperatures, bicarbonate in water is seldom considered to be detrimental.

Sodium - All natural waters contain sodium dissolved from rocks and soils. Sodium is the cation of many salts used in industry and as such is one of the most common ions in process wastes. Some sodium may be removed from solution in water by ion exchange phenomena in the passage through certain soils. Moderate quantities of sodium have little effect on the suitability of water for most purposes. Excessive sodium may be harmful to those suffering from certain cardiovascular-renal diseases (18).

Detergents - A method developed by Degens, et al., (19) for the determination of total anion-active agents in sewage was modified for purposes of this survey. The method of determination depends upon the facts that methylene blue forms complexes with alkyl and aryl sulfates and sulfonates which can be quantitatively extracted from aqueous solutions by chloroform, and that the amount of monochromatic red light absorbed by the chloroform solution, measured spectrophotometrically, is proportional to the concentration of anion-active material in the solution.

DISCUSSION

Water Quality

Coliform Bacteria - Coliform organisms, which sometimes number in the billions per 100 ml. in sewage, are used as an indicator of sewage pollution when found in a stream. However, these organisms may also be found in large numbers in surface runoff from cities and agricultural areas. The Scioto River at the A.E.C. water intake site at low flows is significantly polluted from a bacterial standpoint.

Coliform concentrations found during the survey period exceed the criteria presented in the Public Health Service Manual of Water Sanitation Practice (1). These criteria are:

(a) monthly average coliform concentrations not to exceed 5000/100 ml.

(b) coliform concentrations not to exceed 20,000/100 ml. in more than 5% of the samples.

These criteria were established on the basis of studies conducted about 25 years ago and are intended to serve as rough guides rather than inflexible rules. Many modern water treatment plants are successfully coping with greater bacterial loads without employing unusual treatment processes.

The median coliform values at the four river stations sampled during low flow for a 7-day consecutive period are shown in Figure 8. At station S-54.9 (Higby Bridge) which is 11.3 miles below the Chillicothe sewer outfall and 7.6 miles below the confluence of Paint Creek with the Scioto River, the median number of coliform bacteria per 100 ml.

is 430,000 and the arithmetic average number is 851,000. This indicates that there is extensive pollution from the Chillicothe area at low river flows. The A.E.C. water intake is 32.2 miles below the Chillicothe outfall and 20.9 miles below the sampling station at Higby Bridge. At station S-45.9 (Omega Bridge), approximately 9 miles downstream from Higby Bridge and corresponding to an estimated flow time of 20 hours between the two stations the median coliform MPN per 100 ml. value has decreased to 4,300 and the arithmetic average to 9,160, approximately a hundred fold decrease in 20 hours at an average temperature of 18° C.

At higher stream flows the coliform concentrations at the points of waste discharge will be decreased from those found at low flows. However, the reduction in the coliform density farther downstream at the A.E.C. water intake will not be as great as those which would be found above since a new factor, the death rate of coliform bacteria which is a function of time and temperature, is involved. During high flow the time of transit from a source of pollution is considerably shorter than at low flows, which results in a much lower reduction in the total number of organisms originally present than would otherwise occur. Furthermore, the death rate is lower at low temperature than at high temperatures. As periods of high flow are generally associated with colder temperatures both of these factors will tend to increase the coliform density at the water intake during high flows over those which would be expected from a consideration of dilution alone.

Table 4 shows the estimated flow time between sampling stations for various stream discharges and velocities. For example, from the

Chillicothe sewer outfall to the A.E.C. water intake, a distance of 32.2 river miles, the time of flow at mean discharges of 200 cfs, 660 cfs, and 1320 cfs at Chillicothe was estimated at 42.6 hours, 28.1 hours, and 21.8 hours, respectively. The flow times between the Waverly sewer outfall and the A.E.C. water intake for discharges of 300 cfs, 995 cfs and 1990 cfs were estimated at 5.8 hours, 3.8 hours, and 3.0 hours, respectively. During the field studies in September-October the Scioto River discharge at the A.E.C. water intake averaged about 300 to 320 cfs. The discharge at S-34.0 (A.E.C. water intake) is at or above 1800 cfs 50% of the time. Therefore, it can be expected that primary treated sewage from Waverly will pass the A.E.C. water intake within 3.0 hours, or less, over 50% of the time. Furthermore, at a discharge of 300 cfs which was the estimated average flow during this survey (lowest flows on record occurred the Fall of 1953) it will still pass the intake within less than 6 hours. Though the primary treated sewage from Waverly will be diluted 6 times more at 1800 cfs than at 300 cfs, the coliform bacterial density at the intake will not be 1/6 of that found during this survey since fewer coliform bacteria will die off in 3 hours than in 5.8 hours. (See Figure 22 in ref. 3)

Total Bacteria - The total bacteria present depend in part upon the extent to which the water has been contaminated with decomposing organic matter, either by pollution with sewage or by contact with the surface of the ground. The median value for the number of total bacteria at the 4 stations sampled during a low flow period for 7 consecutive days followed roughly the same trend as the coliform bacteria. Relatively large numbers of bacteria occur in the river water below Chillicothe and are much lower in number 8 miles above Chillicothe and at the A.E.C. intake. The total bacteria count differs from the coliform bacteria count in that while the coliform organisms increase between stations S-45.0 (Omega Bridge) and S-34.0 (A.E.C. water intake), the total bacteria continue to decrease appreciably.

Examination of 7 samples taken at 4-hour intervals during a 24-hour period at station S-34.0 gave maximum, minimum, and median numbers of 8,200, 2,100, and 3,250 bacteria per milliliter, respectively.

Color - The average color of Scioto River water during the 7-day consecutive sampling period was 117 ppm at station S-76.2 (above Chillicothe) and decreased gradually to 64 ppm at station S-34.0 (A.E.C. water intake). Discharge of Imhoff tank effluent at Waverly did not reverse the gradual trend of color decrease in the river.

Examination of water samples obtained during a 24-hour sampling period at S-34.0 showed no variation in color during this period.

It is probable that the color can be reduced to acceptable limits by appropriate water treatment.

Turbidity - The turbidity of the river water averaged 15 ppm at station S-76.2 (above Chillicothe) during the 7-day consecutive sampling period. It increased to 31 ppm at S-54.9 (Higby Bridge), then decreased to 21 ppm at S-45.0 (Omega Bridge). Downstream from this point at station S-34.0 (A.E.C. water intake), a distance of 11 miles, the average turbidity almost tripled to a value of 61 ppm. This value was influenced greatly by the turbidity value of the first day's sample. Discounting that sample the average turbidity still almost doubled to an average value of 38 ppm. The turbidity may have been influenced by construction operations at the U.S. 23 bridge east of Piketon. At the 3 sampling stations above S-34.0 the difference between the maximum and minimum values was never more than 10 ppm for the 7-day period. This would also have been true for samples at station S-34.0 except for the first day's sample which yielded a turbidity value of 190 ppm. The minimum turbidity value at the A.E.C. intake (S-34.0) during the 7-day period was 31 ppm. Of 5 samples taken at 4-hour intervals during a 24-hour period (Sept. 30, 1953) at station S-34.0, the turbidity ranged from 33 ppm to 38 ppm.

At higher flows fine material from gravel washing operations at the Miami Gravel Company (at approximately S-52.7) may add materially to the turbidity in the stream at the intake. The turbidity is likely to be quite variable; however, it can be removed by appropriate water treatment.

Nitrogen - During the 7-day consecutive sampling period the ammonia nitrogen decreased downstream from an average of 6.[illegible] ppm at station S-76.2 to an average of 0.8 ppm at S-34.0. The nitrite nitrogen was fairly low at all stations sampled. The high level of biological activity in the stream evidently causes the nitrite nitrogen to be converted rapidly to nitrate.

The nitrate nitrogen as shown in Figure 8 averaged 0.54 ppm at station S-76.2 and decreased to 0.17 ppm at stations S-54.9 and S-45.0

but reached a maximum average of 0.98 ppm at the A.E.C. water intake (S-34.0). Maximum single values for nitrate nitrogen of 2.0 ppm or greater were obtained for samples from S-76.2 and S-34.0.

The nitrogen as ammonia, nitrite, or nitrate in the stream at station S-34.0 was not excessive during low flow for a raw water supply. However, the nitrogen concentrations in the stream between stations S-76.2 and S-34.0 were sufficient to encourage plankton growth which, though aiding in stream recovery from pollution, will probably impart tastes and odors to the water.

The concentrations of nitrates present in the stream during the period of this survey were considerably lower by at least a factor of 5 than the minimum concentration (10-20 ppm or more) that has been associated with gastro intestinal tract irritation (13), diarrhea and infant methemoglobinemia (14) (15).

Free Residual Chlorination ("Breakpoint" Chlorination) - Water samples from station S-34.0 (A.E.C. water intake) required considerable quantities of chlorine to produce a free chlorine residual ("breakpoint"). Samples taken on September 25, 26, 27, and October 1, required 9, 13, 10 and 10 ppm chlorine, respectively, to reach a free chlorine residual (see Figure 9). Since the quantity of chlorine required to effect a free residual or "breakpoint" is roughly proportional to the amount of ammonia (NH_3) present in the water, high chlorine dosages will be required for free residual chlorination.

Odor Number - The odor number at station S-34.0 (A.E.C. intake) varied during the 7-day sampling period from a minimum of 12 to a maximum of 256. It varied during a 24-hour period from 64 to 96. Objectionable odors must be eliminated during treatment in order to produce a palatable water.

Fluoride - On September 27, 1953, fluoride concentrations of 2.9 ppm and 1.5 ppm were found in water samples from S-76.2 and S-54.9, respectively. A fluoride determination on a 24-hour composite sample taken during September 30, 1953, at S-34.0 (A.E.C. intake) showed a fluoride concentration of 1.6 ppm.

It is believed that the excessive concentration of fluoride in the stream is of industrial origin, probably from phosphate fertilizer production at Columbus. The fluoride content of the water may be expected to be above the allowable limit of 1.5 ppm (2) when the flow at the intake is less than approximately 450 cfs if the present discharge of fluoride containing wastes is continued. Sixty day mean flows of 450 cfs or less may be expected to occur, on the average, about once in five years. The high fluoride content of the stream is being further investigated by the Ohio Department of Health.

Figure 11 shows an estimate of expected reduction in fluoride concentration by increased flows. For example, the curve indicates that at 300 cfs the fluoride concentration will be approximately 2.1 ppm. This will decrease to about 0.5 ppm at 1800 cfs.

A water sample taken from the A.E.C. wells on October 6, 1953, showed a fluoride concentration of 0.06 ppm which is practically negligible.

Dissolved Oxygen - Dissolved oxygen levels in a stream are used as a criterion of pollution by domestic sewage or organic industrial wastes. During the 7-day consecutive sampling period the river was devoid of dissolved oxygen at S-54.9 (Higby Bridge) because of the pollution load from the city of Chillicothe and the Mead Corporation (see Figure 8 and Table 5). The recovery of the stream between S-54.9 and S-34.0 was rapid because of the extensive biological activity in the stream. At station S-34.0 (A.E.C. water intake) the average dissolved oxygen content of the water for the seven samples had increased to 7.2 indicating that the Scioto River is in the process of recovery from the pollution introduced upstream.

The Scioto River is subject to large diurnal variations in dissolved oxygen. Figure 10 shows that during the 24-hour sampling period on September 30, 1953, at station S-34.0 (A.E.C. water intake) the stream was supersaturated with dissolved oxygen from approximately 1300 hour to 2100 hour with a maximum value of 11.6 ppm dissolved oxygen at 1600 hour. The minimum value for dissolved oxygen during the 24-hour period was 5.4 ppm and occurred at 0600 hour. Additional dissolved oxygen determinations made on September 22, and 26, (Table 9) indicated that the DO varied from 5.4 ppm up to over 19 ppm (over 200 percent of saturation at the indicated water temperature). The difference in the results for the maximum values was probably due to the difference in the amount of sunlight acting on plankton on the two days.

As indicated by Figure 10 the lowest dissolved oxygen levels extended from about 0500 hour to 0700 hour. Most of the samples for the 7-day sampling period were collected between these hours so that the effect of oxygenation by algae through photosynthesis would be minimized.

At the low flows encountered on the Scioto River during this survey the location of the critical point or point of maximum deoxygenation occurs about 21 miles upstream from the A.E.C. water intake (see Figure 8). However, at higher flows the maximum oxygen deficit will probably occur considerably closer to the A.E.C. intake. The deficit will be less during sustained high flows than at low flows, however.

Biochemical Oxygen Demand (5-day, 20° C. BOD) - Biochemical oxidation of organic material is performed by varied bacterial and biological organisms which are present or develop in the stream and which derive their food and energy from organic material. A small amount of naturally occurring organic material is found in nearly all streams even though no man made pollution (industrial or domestic) is discharged to the stream. Such naturally occurring pollution, which is caused by surface runoff or drainage carrying organic plant material into the stream, seldom exceeds 1 ppm unless the stream consists largely of swamp water.

During the 7-day consecutive sampling period the average BOD in the stream was 4.7 ppm, 9.1 ppm, 4.8 ppm and 5.7 ppm at stations S-76.2, S-54.9, S-45.0 and S-34.0, respectively (see Figure 8). On September 30, 1953, during a 24-hour sampling period at station S-34.0 the BOD varied from a minimum of 5.6 ppm to a maximum of 8.6 ppm and averaged 7.4 ppm for the 24-hour period (see Figure 10 and Table 7).

The BOD average of 5.7 ppm at S-34.0 (A.E.C. water intake) for a 7-day period during low summer flow is higher than is desirable and is an indication that the water contains organic pollution which would add to the difficulty of treating it to obtain satisfactory water. Since the period during which these samples were taken is one of the driest on record, it may reflect conditions at their worst from a BOD standpoint. For the greater part of the year there is considerably greater river discharge affording more dilution which in turn will decrease the concentration of organic matter present with its accompanying biochemical oxygen demand. However, shorter flow times at higher flows will tend to reduce somewhat the effect of the increased dilution. Nevertheless, the water will be of better quality at higher stages except for the first period of high flow following a drought when organic matter and silt which had settled during low flow are flushed out.

Water Temperature - Temperature data obtained on the Scioto River between 0500 and 0800 showed little variation during the 7-day consecutive sampling period, September 23 through 29. The temperature readings ranged between 17° and 19° C. at stations S-76.2, S-45.0 and S-34.0 (A.E.C. intake) and between 18° and 20° C. at station S-54.9.

Temperature readings on the stream were made every two hours during a 24-hour period on September 30, 1953. These readings ranged between 19° and 23° C. and averaged 20° C. During this period the river depth was very shallow because of low flow due to drought conditions and the stream temperature followed air temperature changes fairly rapidly. It is likely that much higher water temperatures would prevail during low flow in the summer months. Temperatures as high as 26° C. were recorded during a previous Scioto River survey (20).

Total Hardness - The total hardness values at all four sampling points on September 28, 1953, and at station S-34.0 (A.E.C. water intake) on September 30, 1953, were not significantly different. The total hardness averaged 340 ppm for all tests. The maximum variation was less than 2%. A comparison of the results of our analyses with those of the Ohio Department of Health as shown on Table 8, indicates that a lower total hardness should be expected at higher flows. Total alkalinity when expressed as $CaCO_3$ equals carbonate hardness in all Scioto River samples analyzed. Figure 13 may therefore be considered a rough estimate of the effect of flow on carbonate hardness as well as alkalinity.

Total Alkalinity - The total alkalinity varied slightly between sampling stations, the average value at S-34.0 during the 7-day sampling period was 295 ppm as $CaCO_3$ while at S-76.2 it averaged 301 ppm. The total alkalinity and therefore the carbonate hardness can be expected to decrease considerably with increased flow. Figure 13 shows that the alkalinity is approximately 300 ppm at a flow of 300 cfs, and can be expected to equal or exceed 210 ppm at flows of 1800 cfs or less which will occur 50% of the time.

Chloride - The chloride content of the stream on September 29, 1953, was constant from station S-76.2 to S-34.0 and amounted to 46-47 ppm Cl^-. There was little variation in the chloride concentration during a 24-hour period at S-34.0 on September 30, 1953, when it ranged between 42-44 ppm Cl^-. Figure 12 shows the expected decrease in chloride concentration with increased flows. For example, one would expect a chloride concentration of about 40 ppm in the Scioto River at the A.E.C. water intake below Chillicothe for a flow of 300 cfs and about 7 ppm at 1800 cfs.

Hydrogen Ion Concentration (pH) - During the 7-day sampling period the pH varied slightly at each sampling station and was slightly higher at station S-34.0 than at the upstream stations. The pH ranged from 7.9 to 8.4 during this period. On September 30, 1953, during a 24-hour period the pH ranged from 7.8 to 8.2. The lower values occurred generally during the hours of darkness and are attributed to CO_2 formation in the process of respiration by algae present in the stream.

Mineral Analysis - The results of the mineral analyses of two samples from the Scioto River and one sample from the A.E.C. wells are presented in Table 8, and compared with results of past analyses by the U. S. Geological Survey (11) and the Ohio Department of Health (21). As would be expected the results indicate that the river is much more highly mineralized at low flows than at high. The total dissolved solids found in the two samples averaged 553 ppm. Figure 14 shows the expected decrease in dissolved solids concentration from increased stream flow. While the dissolved solids concentration amounted to 550 ppm at 300 cfs, it can be expected to decrease to about 330 ppm at a flow of 1800 cfs.

From a drinking water standpoint the dissolved solids and dissolved minerals constituents present in the Scioto River with the exception of fluoride are not excessive. An alum application of 260 ppm would be possible without increasing the $SO_4^=$ content above the 250 ppm level suggested in the Public Health Service Drinking Water Standards (1).

The well water was considerably lower in dissolved solids (354 ppm) than the Scioto River water at the time the river was sampled. It is estimated that the well water contains of the order of 40 ppm of free CO_2. A more exact value will be obtained subsequently.

Synthetic Detergents - Synthetic detergents are rapidly attaining dominance as cleansers in industry and in the household. Sales rose from none in 1928 to 0.1 billion pounds in 1941 and to 1.5 billion pounds in 1952. Consumption is expected to exceed 2 billion pounds annually in the near future.

In most domestic and industrial applications, detergents eventually find their way into streams which are used as sources for potable water. Because of the phenomenal growth in the use of detergents, the possibility of taste and odor and coagulation problems arising from this source of pollution has aroused much general interest and considerable concern in some localities.

The recently published "Encyclopedia of Surface-Active Agents" (22) lists more than 2500 commercial brands. The anionic-active detergents of chief interest to those concerned with water treatment are the alkyl aryl sulfonates and the fatty acid sulfates, as these form the base for 83% of the products sold. The ordinary household package of synthetic detergent contains 30-35% of pure organic detergent (23). The other principle ingredients include such compounds as sodium tripolyphosphate, tetrasodiumpyrophosphate, carboxy-methylcellulose, sodium sulfate, sodium chloride, other alkaline builders, small amount of organic builders, perfumes, and fluorescent dyes. The one essential ingredient common to all of the so called "detergents" is the surface active agent, often referred to in analyses as the "pure organic detergent."

Many of these auxiliary components are fully as important to the water works operator as the surface active agent itself. The polyphosphates particularly may have a great influence on colloidal behavior. Phosphorous is generally recognized as the key element in the stimulation of the growth of algae (24).

The ability of a detergent to deflocculate or disperse the soil is the aspect of detergency which most directly opposes the results desired in water treatment. Some work (24) has indicated that as little as 3-5 ppm of detergent (the complete product as offered for retail or industrial sale) will interfere with coagulation and settling.

Other studies (25) have shown that the minimum concentration of detergent (the complete product) required to produce a perceptible taste varied from 0.6 to 3.0 ppm when various types of detergents were tested. The minimum concentration of detergent required to produce a perceptible odor varied from 0.2 to 2.0 ppm. In general the action of chlorine up to 10 ppm intensified the taste and odor.

In order to aid in properly assessing the quality of the Scioto River water for use as the source for a potable water supply, the following determinations for anionic-active agent have been made.

Station	Date Collected	Date Analyzed	I ppm Anionic - Active Agent (1)	II ppm Detergent (3)
S-34.0	1/5/54	1/6/54	0.80 (2)	3.2
S-54.9	"	"	0.83 (2)	3.3
S-46.2	"	"	0.93 (2)	3.7

---

(1) As ppm of sodium alkyl sulfate
(2) Average of two replicates
(3) The data in Col. I represent the total anionic-active agent expressed as ppm sodium alkyl sulfate. If it is assumed that the molecular weight of the sodium alkyl sulfate is 288 and the average molecular weight of the most common surface-active agent in household detergents is 348, and further, that the concentration of surface-active agent in household detergents is 30%, then the values in Col. II can be computed.

It is probable that sufficient detergent was present in the Scioto River during the Fall of 1953 to cause some water treatment difficulties and higher concentrations would almost certainly cause taste and odor problems and interfere with coagulation.

SECTION II - SPECTROGRAPHIC STUDIES

SEMIQUANTITATIVE SPECTROGRAPHIC ANALYSIS OF METALIC CONSTITUENTS

Introduction

Samples of water from various points on the Scioto River and from the A.E.C. wells were subjected to semiquantitative spectrographic analysis to determine the concentrations of the trace metals listed in Table 10.

Procedure

One liter portions of the thoroughly mixed water samples were removed and transferred to clean Griffin beakers (Pyrex). After the addition of 5 ml of concentrated nitric acid, reagent grade, the samples were evaporated to 30 ml, an additional 5 ml of acid being introduced during the evaporation. The concentrated samples were diluted to 50 ml, using 3-4 ml nitric acid and single distilled water. After thorough mixing, 0.1 ml portions were transferred to the waterproofed center post type craters (3 mm deep) of spectroscopically pure graphite electrodes previously one-quarter filled with a 1:2.5 by weight mixture of lithium chloride and graphite (26). The electrodes were dried at 105°C. for one hour and burned for 30 seconds as anodes in a 220 volt D.C. arc, operating at 9 amperes with a 10 mm arc gap, using a Bausch and Lomb large Littrow spectropraph with quartz optics. After photographic processing, the sample spectrograms were compared in a Jarrell-Ash comparator with the spectrograms prepared from the series of standard solutions under identical exposure conditions. Concentration estimations were made by matching the spectral lines of the known quantities of trace elements present in the standard solutions.

Results

The results of semiquantitative analysis of Scioto River and A.E.C. well samples, presented in Table 10, indicate that the concentrations of toxic heavy metals were low in all samples. There was no indication that any of the heavy metals were present at or even approaching the toxic limits for finished waters.

Selenium, which is limited to 0.05 ppm in the U. S. Public Health Service Standards (2), is not determinable by means of arc spectrographic analysis. The toxic effects of selenium are ordinarily associated with the consumption of food rather than water (27), and it is not expected that selenium will be a water quality problem. Chemical determination of selenium will be made on water samples collected during the second survey period.

TABLE 10

SEMIQUANTITATIVE SPECTROGRAPHIC ANALYSIS OF METALLIC CONSTITUENTS

Parts per Million

Sampling Station	Scioto River							
	A.E.C. Water Intake S-34.0			Higby Bridge S-54.9	Above Chillicothe S-76.2	Above Columbus S-135.0	A.E.C. Wells	PHS Drinking Water Standard (Ref. 2) Finished Water
Element	9/24/53	24-Hr. Comp. 9/30/53	11/11/53	11/11/53	11/11/53	11/11/53	10/6/53	
Antimony	<0.01	<0.01	-	-	-	-	<0.01	-
Arsenic	<0.01	<0.01	-	-	-	-	<0.01	0.05
Barium	0.08	0.08	0.05	0.08	0.05	0.08	0.05	-
Beryllium	<0.01	<0.01	-	-	-	-	<0.01	-
Bismuth	<0.01	<0.01	-	-	-	-	<0.01	-
Cadmium	<0.01	<0.01	-	-	-	-	<0.01	-
Chromium	0.005	0.005	<0.005	0.01	0.01	0.01	0.005	0.05*
Cobalt	<0.01	<0.01	-	-	-	-	0.01	-
Copper	<0.1	<0.1	-	-	-	-	<0.01	3.0
Lead	0.02	0.01	0.02	0.06	0.02	0.008	0.005	0.1
Mercury	<0.01	<0.01	-	-	-	-	<0.01	-
Molybdenum	0.005	0.005	0.005	0.005	0.005	0.005	0.005	-
Nickel	<0.01	<0.01	-	-	-	-	<0.01	
Tin	<0.01	<0.01	-	-	-	-	<0.01	
Titanium	0.01	0.02	<0.01	0.02	<0.01	0.01	0.005	-
Tungsten	<0.01	<0.01	-	-	-	-	<0.01	-
Vanadium	<0.01	<0.01	-	-	-	-	<0.01	-
Zinc	<0.01	<0.01	-	-	-	-	<0.01	15.0

*As hexavalent chromium

SECTION III - CARBON FILTER STUDIES

RECOVERY OF ORGANIC MATERIALS BY THE CARBON FILTER METHOD FROM THE SCIOTO RIVER AND THE A.E.C. WELLS NEAR PIKETON, OHIO SEPTEMBER 22, 1953 to OCTOBER 15, 1953

Introduction

The carbon filter method (28) was used to collect organic materials from the Scioto River at the A.E.C. water intake site near Piketon, Ohio, and from the A.E.C. wells southwest of Piketon.

Organic substances in water may cause taste and odor difficulties (29), interfere with normal water treatment processes such as coagulation and could conceivably have toxic or other physiological effects on man. It was the purpose of this phase of the study to investigate the types and quantities of organic materials present in the river and well supply.

Sampling Methods

The concentration of organic materials in surface waters is usually small. Specific and sensitive tests have not been developed for most of the materials that may be present. Concentration procedures are necessary to collect materials for analysis. Organic materials are absorbed from the water by passing it through small filters containing active carbon. A representative sample was collected from the river by means of a cellar type drain pump. This pump was supported on a wooden frame and pumped the water through a garden hose to a 500 gallon concrete tank placed on the river bank. The water from the tank was then pumped by means of a metering type chemical feeder through two carbon filters in series. The filters were of pyrex glass construction and were

3 inches in diameter and 18 inches in length. The first filter contained Cliffchar 4 x 10 mesh carbon (Cliffs Dow Chemical Company, Marquette, Mich.) and the second filter contained Nuchar C-190 unground carbon (West Virginia Pulp and Paper Company, 230 Park Avenue, New York). The latter carbon is more active but cannot be used alone due to flow difficulties created by passage of the raw river water through the carbon. Five single filters were used during the period of study. A picture of the field installation of the filters will be found at the end of this report. A single filter containing C-190 carbon was placed on the well supply during the period of the survey.

Experimental Recovery of Materials from the Carbon: The carbon was returned to the laboratory upon completion of the field run and permitted to dry at room temperature. The carbon was then extracted with chloroform in a large Soxhlet type extractor for 50 hours. The chloroform was distilled leaving an organic residue consisting of those organic materials originally in the water that were less volatile than chloroform. The residue underwent drying and was then weighed. The actual recoveries of organic materials from these samples are shown in Table 11.

The carbon filter technique is semiquantitative and the recoveries should be considered as only roughly indicative of the amount of organic materials actually present. For purposes of analyses the extracts from the filters used on the river were composited. On this basis a total recovery of 6.23 grams of material was recovered from 2800 gallons of water equivalent to a concentration of 587 ppb or approximately 0.6 ppm. Table 12 shows the recoveries of organic materials obtained from various

TABLE 11

RECOVERIES OF ORGANIC MATERIALS FROM CARBON FILTERS ON SCIOTO RIVER WATER AND A. E. C. WELL SUPPLY

Dates of Operation	Lab. No.	Type of Filter	Gallons Filtered	Recovery	
				Grams	ppb*
1953					
9/24-9/27	423-I**	Cliffchar	484	0.2342	128
	423-II**	C-190	484	0.7128	389
9/28-10/13	424-I**	Cliffchar	2315	0.5423	62
	424-II**	C-190	985	2.2271	608
	424-IIa**	C-190	1330	2.5144	497
9/28-10/13	425 ***	C-190	5400	0.9154	45

* ppb - parts per billion

** Scioto River Water

*** A.E.C. Well Supply

TABLE 12

RECOVERY OF ORGANIC MATERIALS FROM VARIOUS WATERS AS RELATED TO TASTE AND ODOR PROBLEMS

Location	Type of Water	Concentration of Organics in Water ppb	Known Occurrences of Taste and Odor Problems
Scioto River at Piketon, Ohio	Raw	600	—
Scioto River above Columbus, Ohio	Raw	38-82	Occasional outbreaks in algae season
Ohio River at Cincinnati, Ohio	Finished	70-500	Few in late spring and summer-bad in late fall and winter
Lake Michigan at Chicago, Ill.	Raw	25-50	Frequent outbreaks
Kanawha River at Nitro, W. Va.	Raw	150-3000	Present at all times
Lake Huron at Saginaw, Mich.	Finished	25	None

localities using the carbon filter method and notations as to whether taste and odor is a problem in these places. It may be concluded by examination of this table that the Scioto River is a likely source of taste and odor at the Piketon site. The types of materials present as well as the quantities have much influence on the occurrence of taste and odor.

Chemical Analysis

The complex character of the materials recovered may be better understood when it is considered that the organic materials in a stream may result from land run-off, the discharge of industrial and domestic waste, and the diverse products of metabolism and decay of aquatic plants and animals. Sedimentation, aeration, volatilization and the natural purification forces within the stream all affect these materials. It is not practicable to attempt complete identification of these complex mixtures. Certain determinations can be made in a reasonable length of time and yield information not otherwise obtainable.

Once the total extract has been recovered and weighed a portion of it is separated into chemical groups or classes by solubility differences. The total extract is not usually very soluble in water and may not readily be dissolved in ether, chloroform or other organic solvents.

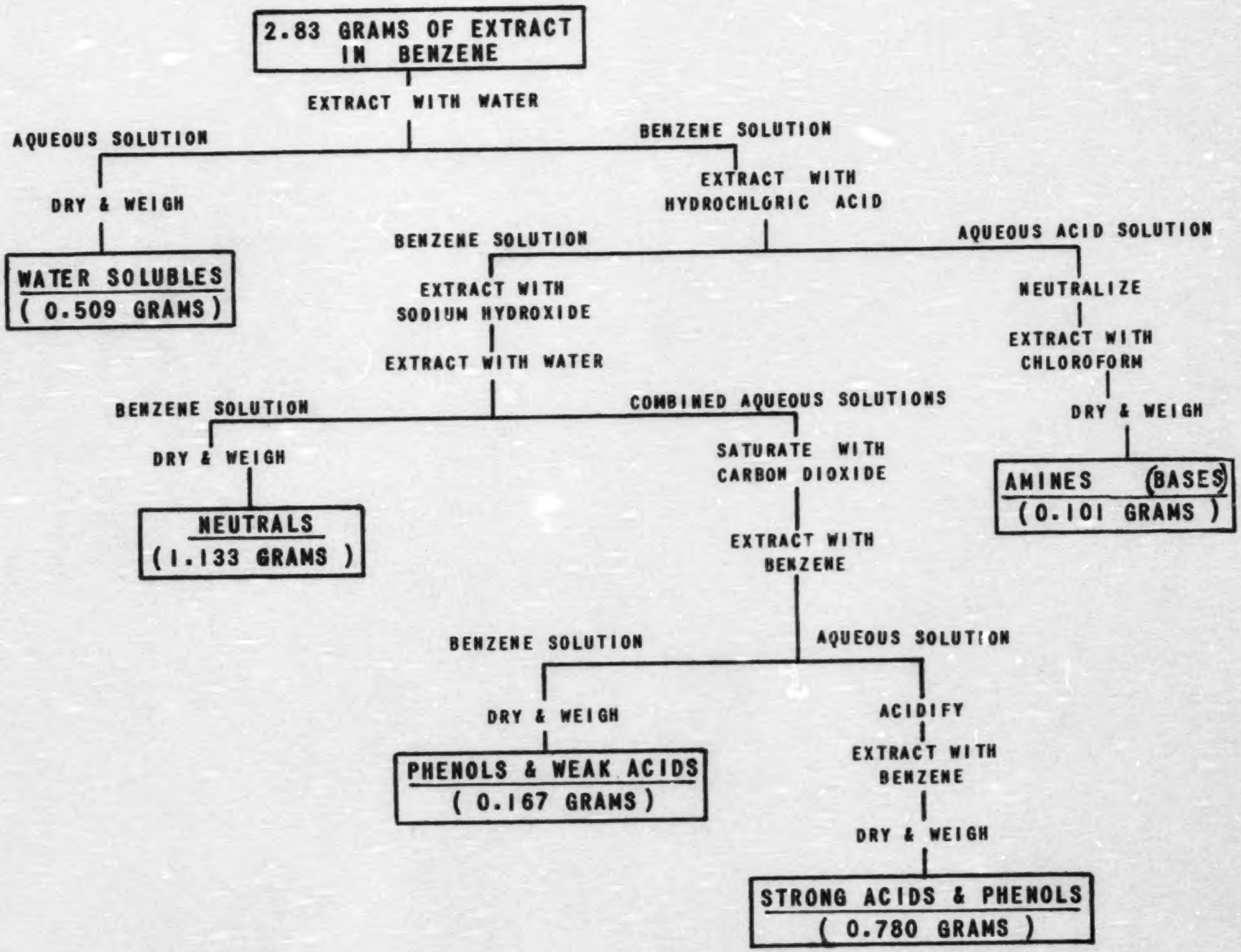
A portion of the total extract weighing 2.830 grams from the Scioto River was subjected to group analysis. The material was first dissolved in benzene. Groups were separated in accordance with the schematic diagram shown in Figure 15. The recovery of these groups is shown in Table 13.

The neutral materials constituted 40% of the total organic extract sample. Such materials would be expected to be more resistant to chemical and biological oxidation than would the more polar materials. Observation of a large number of different water samples has shown that the neutral materials are generally present in the greatest concentration of all the groups. The neutral substances usually have high odor intensities. The objectionable quality of the odor of the total sample is often closely associated with the neutral group.

Acidic materials are usually separated into two groups by the scheme used. Weak acids and the weakly acid phenolic compounds including ordinary phenol would be found in the weak acid fraction. More highly substituted phenols and strong organic acids would be found in the strong acid group. In these samples the phenolic compounds usually associated with taste and odor were not observed or if present were in concentrations too low to be significant. Grouping the acidic materials shows that these materials constitute 34% of the sample. These materials most likely originate from biological sources. The materials have a fairly high odor intensity.

The organic base materials constituted less than 4% of the total sample. Organic bases, largely amines, are noted for odor properties and cannot be disregarded in considering odor problems. The materials have high odor-intensities and the quality is usually quite objectionable.

"Water Soluble Material" as used here refers to those substances readily soluble in water and having a partition coefficient favorable to water as compared to ether, chloroform, benzene or the organic solvents used in the separation procedure. These materials have the least odor



SEPARATION OF ORGANIC GROUPS — SCIOTO RIVER

FIGURE 15

TABLE 13

GROUPS RECOVERED FROM TOTAL ORGANIC EXTRACT - SCIOTO RIVER

Group	Weight Recovered grams	Per Cent of Original Weight
Water Solubles	0.509	18.0
Amines (Bases)	0.101	3.6
Weak Acids and Phenols	0.167	5.9
Strong Acids and Phenols	0.780	27.6
Neutrals	1.133	40.1
	2.690	95.2

TABLE 14

COMPOSITION OF ORGANIC EXTRACTS FROM VARIOUS WATERS

		Group Recoveries Per Cent Composition of Extract				
Source of Water	General Pollutional Load in Area	Water Solubles	Amines (Bases)	Weak Acids & Phenols	Strong Acids & Phenols	Neutrals
Scioto River A.E.C. Water Intake Site	Domestic Sewage-Light Industrial Wastes	18.0	3.6	5.9	27.6	40.1
Mt. Clemens, Michigan Lake St. Clair	Industrial-Oily	2.2	1.6	16.9	12.1	63.0
Waukegan, Illinois	Natural-Possible Biological Wastes	13.6	3.8	18.0	7.0	46.8
Richmond, Indiana Activated Sludge Effluent	Domestic Sewage	8.9	-	16.7	21.2	35.5

intensity and are the least objectionable of any of the groups.

A comparison of the Scioto water with other water as to relative concentrations of the various organic groupings is of interest. Table 14 shows this comparison.

The Mt. Clemens samples show proportionally more neutral materials than the other samples. This would be expected in view of the oily nature of the materials recovered from Mt. Clemens. Waukegan water may be subjected to certain industrial pollution, but at the time of sampling it appeared the usual natural conditions prevailed.

Infrared Absorption Characteristics of the Extracts from the River Samples

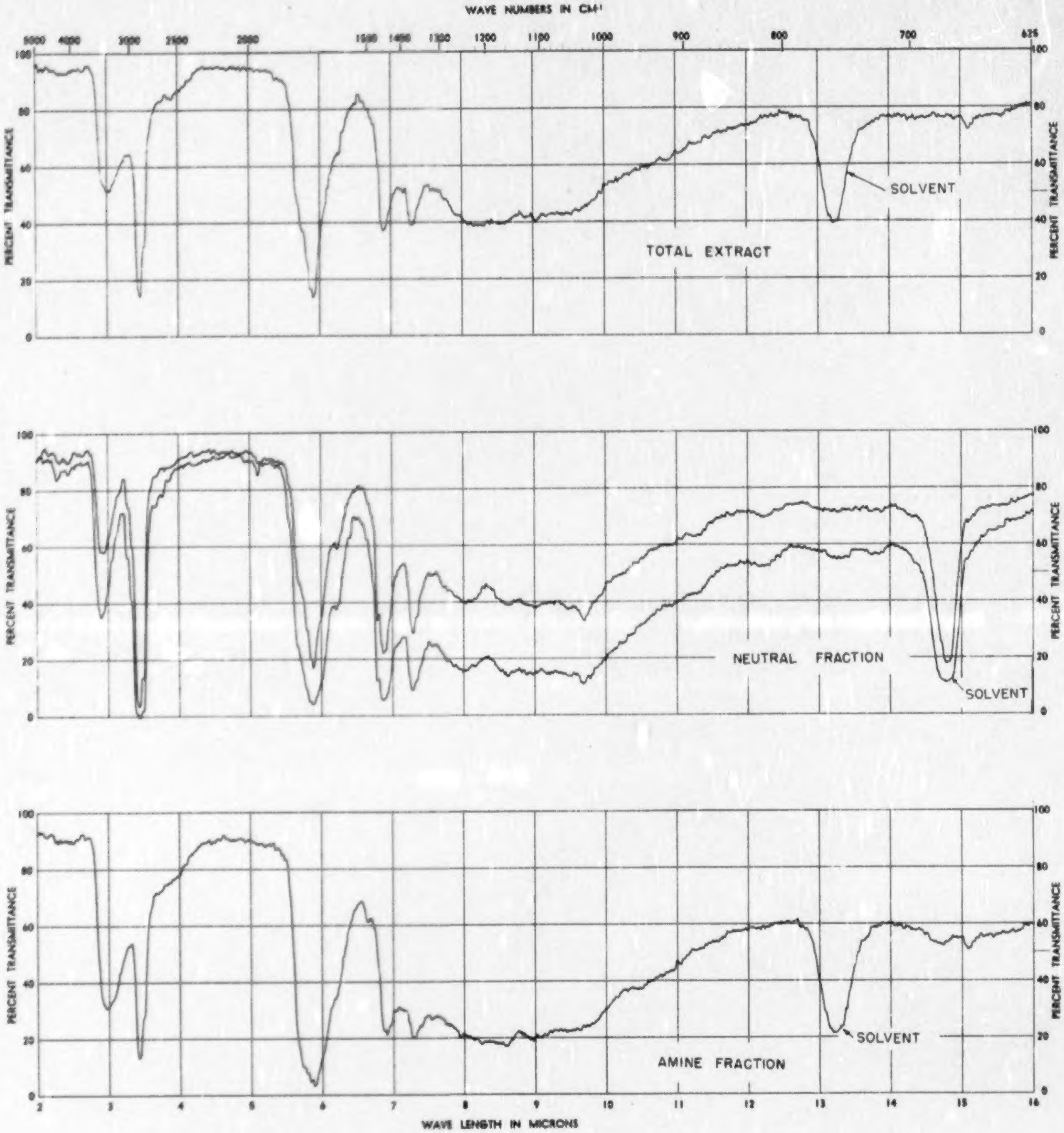
To determine further the chemical nature of the carbon filter extracts from the Scioto River infrared spectra were run on the total extract and the separated groups. Infrared spectra on materials of the type extracted from the Scioto River provide information as to the general character of the material. If unusual or specific materials are present the infrared will be helpful in revealing the substances. Oils for example can be detected readily. Wastes from the chemical manufacture of synthetics are also likely to be detected upon infrared examination. However, materials of a general biological nature extracted from water do not give clear cut infrared spectra. The principal conclusions from the infrared spectra are that the organic materials recovered from the Scioto River consist of highly oxygenated materials. The intense absorptions in the 3.0 micron region and the very strong absorptions in the 5.9 micron region confirm the presence of acidic materials, ester type substances and possibly alcohols, aldehydes and related materials. The spectra of the various groups have the same general properties with minor variations, indicating further the complexity of the biological materials present. These spectra are presented in Figures 16 and 17.

Well Water Sample

The carbon filter from the A.E.C. well yielded 45 ppb of organic materials. No chemical separations were made on this sample. The infrared spectrum of this extract was distinctly different from the spectra of the river extracts. The principal indications from this examination are that aliphatic and aromatic hydrocarbons are present along with a small amount of oxygenated materials. It is probable that the sample is lubricating oil from the well pump along with some small quantity of other organic materials. No particular significance is attached to this sample. No water has yet been encountered where some recovery of organics could not be obtained.

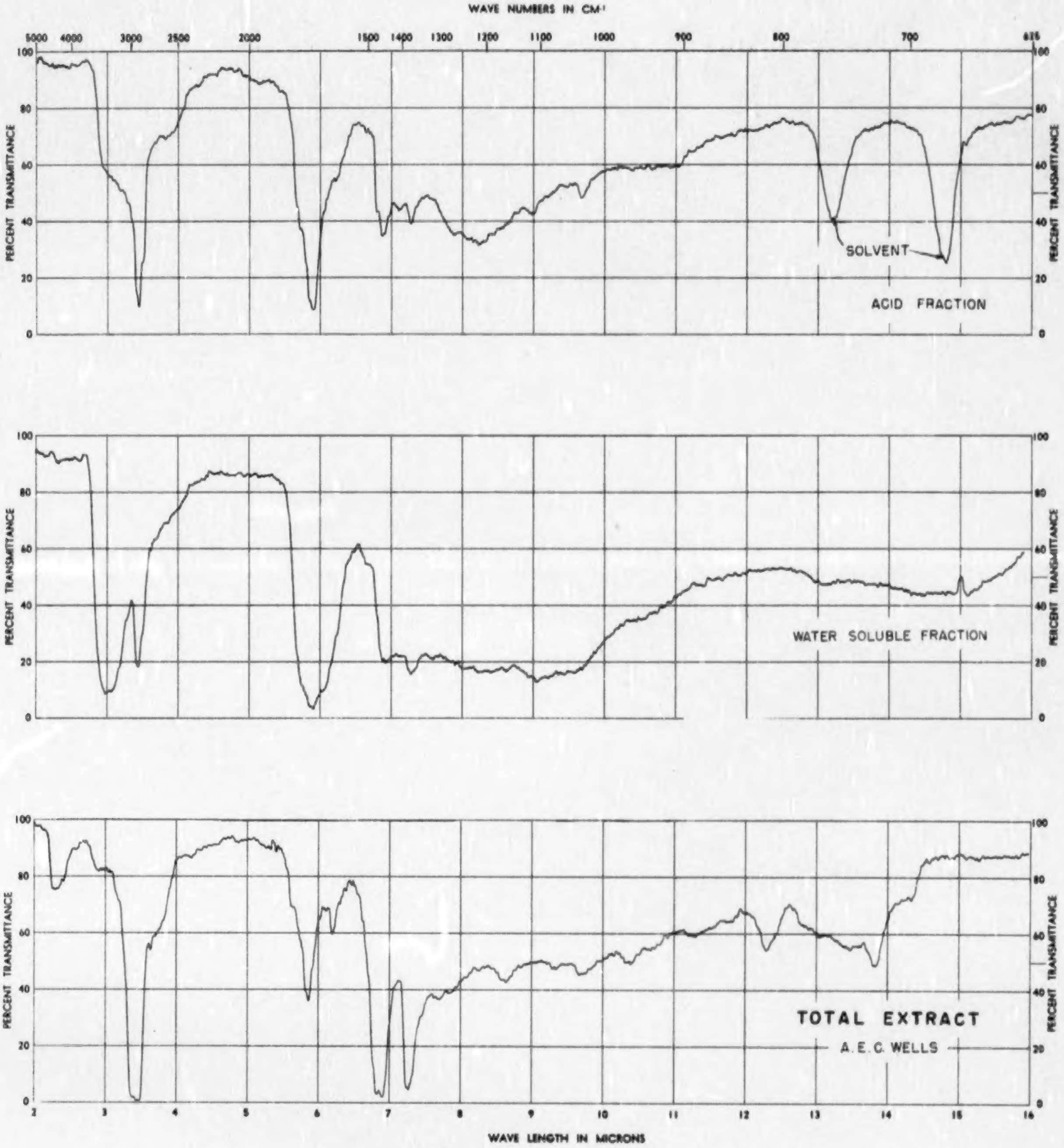
Odor Characteristics of Extracts

The threshold odor, that is the point where odor is first detected, of the total and group extracts was determined. A weighed amount of each extract was dissolved in odor free water to prepare a solution of 6 ppm. This solution was then diluted to appropriate concentrations so that in a series increasing in concentration the low end of the series would be negative and the high end of the series would be positive to the panel of observers. Three or four observers were used for each odor determination and the geometric mean was computed as the threshold odor of the sample being tested. Table 15 shows the odor results.



INFRARED-CARBON FILTER EXTRACTS
SCIOTO RIVER

FIGURE 16



INFRARED-CARBON FILTER EXTRACTS

SCIOTO RIVER (EXCEPT AS NOTED)

FIGURE 17

TABLE 15

THRESHOLD ODORS OF ORGANIC EXTRACTS - SCIOTO RIVER

Sample	No. of Observers	Threshold Odor p.p.b. High	Low	Geometric Mean
Total Extract	4	64	16	38
Water Soluble Group	3	2048	1024	1230
Amine (Base) Group	3	64	32	50
Weak Acid & Phenol Group	3	256	32	128
Strong Acid & Phenol Group	4	256	128	212
Neutral Group	3	64	16	38

TABLE 16

CHARACTERIZATION OF ODORS OF ORGANIC EXTRACTS - SCIOTO RIVER

	Concentrated	Dilute
Total Extract	Vegetable - Decay	Musty
Water Soluble Group	Caramel-Mild-Sweet	Sweet Mild
Amine (Base) Group	Tobacco like	Tobacco
Weak Acid & Phenol Group	Wood Distillation Products	Woody
Strong Acid & Phenol Group	Rancid	Oily
Neutral Group	Vegetable - Oily	Musty Oily

The neutral and amine groups are not significantly different in threshold values and are close in value to the total extract threshold. The phenolic and acid groups are next in order of odor intensity. The water soluble group had the lowest odor intensity. From the characteristics of these materials and the low threshold odors it is concluded that difficult and unpleasant taste and odor problems would be expected from water drawn from the Scioto River at this site under the flow conditions encountered at the time of this study.

Chlorination Effects: - Chlorine may tend to intensify tastes and odors in water particularly if added in amounts inadequate to meet the chlorine demand of the water. The various extracts were prepared in 1 ppm concentrations in odor free water and dosed with approximately 1 ppm of chlorine. This treatment did not markedly alter the odor characteristics of the extracts in solution. Likewise taste tests of the chlorinated and unchlorinated samples were not very different. It would be expected that phenols if present would respond to chlorination by an increased taste intensity. This was not the case and this evidence along with other observations indicates that phenols likely to react with chlorine are not present in these samples. It is possible of course that other chlorine dosages may produce different effects.

The concentrated extracts had very pronounced odors. Odors of concentrated materials are usually different in high dilution and this was the case in this series of samples. Descriptions of these odors by chemists familiar with odor problems are presented in Table 16.

Discussion

Aside from possible taste and odor, the effects of consuming small quantities of organic materials in water are unknown. However the public will often reject a bacteriologically safe water having bad taste and odor and seek a palatable water which may be of questionable sanitary quality. Production of a consistently palatable water is a practical necessity.

SECTION IV - BIOLOGICAL STUDIES

SCIOTO RIVER STUDIES

THE POPULATION OF PHYTOPLANKTON AND RELATED ORGANISMS DURING SEPTEMBER, 1953

Introduction

A previous study of the plankton of the Scioto River, extending from 1937 to 1939, indicated that the stream was unusually rich in Algae (3). These organisms are significant not only as indicators of the sanitary condition of the stream but also because they directly influence the water quality and the treatment required. During the coming year the plankton of the Scioto River is to be studied to determine its possible effects upon the water which will be withdrawn from the stream at Piketon for use in the A.E.C. plant. This preliminary report on the plankton and related organisms is limited to those investigations which were conducted during September, 1953.

A preliminary survey of the river was made on September 3, 1953. At this time plankton samples and samples of floating algal mats and bottom algae were collected from four points between Chillicothe and Piketon. A later, more extensive investigation was conducted on this same stretch of river during September 22 to 25. Plankton samples were collected at twenty stations, and bottom samples and samples from the floating algal mats were taken at some of these same points. These collecting stations are listed in Table 17 and their locations are indicated on the map in Figure 18.

Plankton samples were concentrated 20 to 1 by use of the Foerst plankton centrifuge, and counts were made using a microscope with a magnification of 430 diameters together with a Palmer plankton cell.

Net plankton samples were concentrated in the field and were analyzed under a magnification of 100 diameters with a Sedgwick-Rafter plankton cell. Bottom samples and samples of algal surface mats were checked for the relative abundance of different types of algae.

Visible Algal Growths

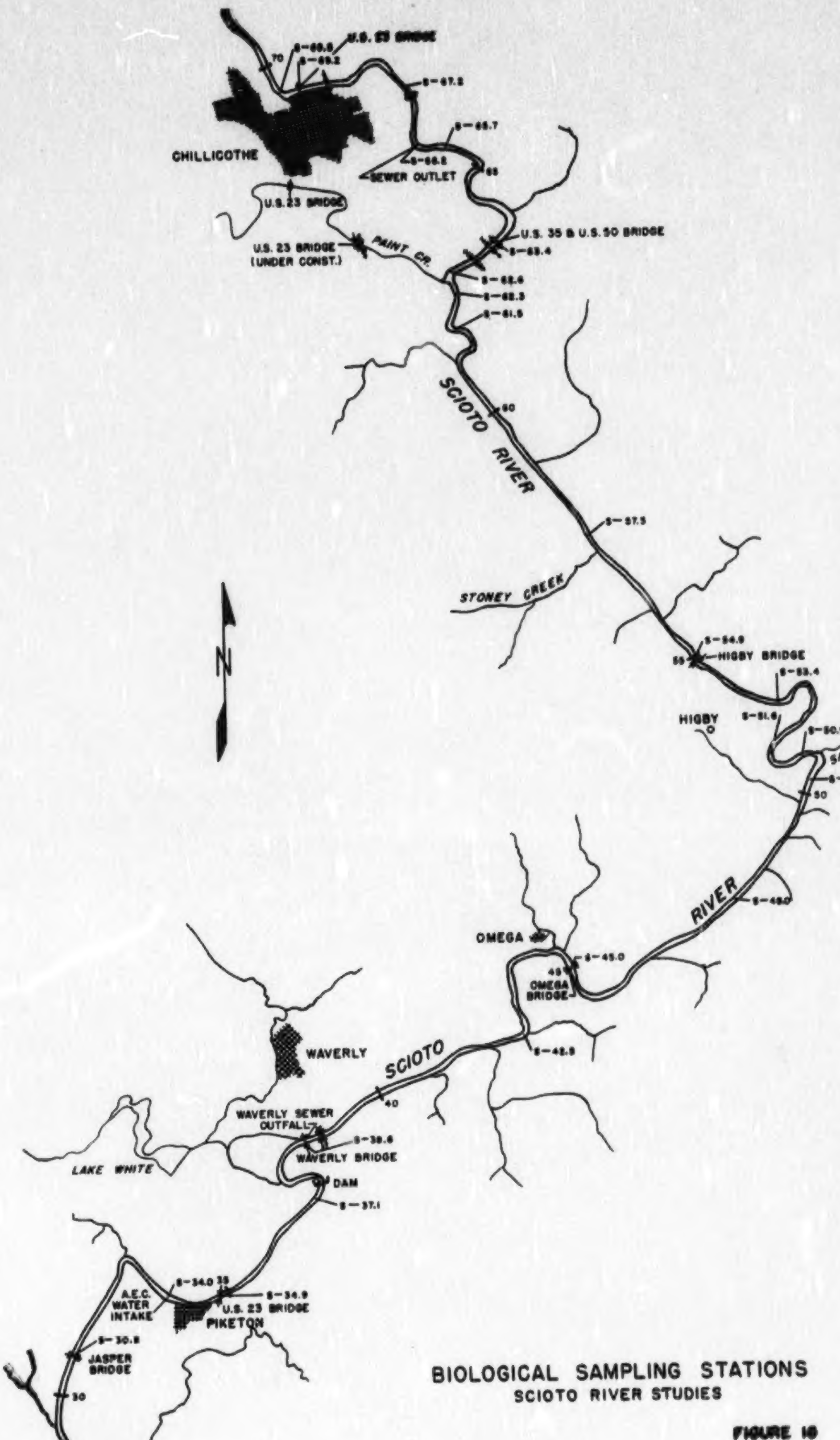
Masses of algae, from bottom samples and floating mats, whose size or abundance made them visible even to the naked eye, were examined for the genera present and for their relative abundance. The more common forms are recorded by stream sections in Table 18.

Cladophora was the most common and abundant of the visible algae and was present in all sections from Chillicothe to the A.E.C. water intake as indicated in Table 18. Hydrodictyon and Oedogonium were common in the upper sections of the stream only. Oscillatoria, Spirogyra, Stigeoclonium, and Tetraspora were abundant only in the Higby Bridge section. The freshwater red alga, Audouinella, was present in 4 sections (Table 18) while the large diatom, Biddulphia. was present in all five sections. These last two genera are unusual forms and are only rarely encountered in this country.

The distribution by sections (Table 18) of the twelve visible algae collected would indicate that they were best represented as a group in the Higby Bridge section, probably due to the presence of nutrients resulting from the decomposition of organic wastes discharged from Paint Creek and the Chillicothe sewer outfall. It is evident, also, that the numbers and abundance of the various visible algae at the A.E.C. water intake were less than in all other sections upstream. Future studies, however, may show a change in this apparent condition. A freshet

TABLE 17
SCIOTO RIVER STUDIES
BIOLOGICAL SAMPLING POINTS

River Miles	Location
S-69.5	Chillicothe, above U. S. Route 23 bridge
S-67.2	Chillicothe, above sewer outfall
S-65.7	Chillicothe, 1/2 mile below sewer outfall
S-63.4	Bridge, U. S. Rts. 35 and 50, east of Chillicothe
S-62.6	Above mouth of Paint Creek
S-62.3	First riffle below Paint Creek
S-61.5	One mile below Paint Creek
S-57.5	Above Stoney Creek
S-54.9	Higby Bridge
S-53.4	1-1/2 miles below Higby Bridge
S-51.6	Second big bend below Higby Bridge
S-50.9	First riffle below gravel plant
S-50.2	Watson Road, east point of convergence with stream
S-48.0	River road (Co. #28) west point of convergence with stream
S-45.0	Omega Bridge, Route 335
S-42.5	East-West Road on south side, east point of convergence with stream
S-38.6	Waverly Bridge, U. S. Route 220, and sewer outfall
S-37.1	Below dam, south of Waverly
S-34.9	Piketon Bridge, U. S. Route 23
S-34.0	A.E.C. Water Intake Site



BIOLOGICAL SAMPLING STATIONS
SCIOTO RIVER STUDIES

FIGURE 18

TABLE 18 - SCIOTO RIVER
DISTRIBUTION OF VISIBLE ALGAE

Sections Included	Chillicothe Section	Below Chillicothe Sewage Outlet & Paint Creek	Higby Bridge Section	Omega Bridge Section	A.E.C. Water Intake
Mileage from River Mouth	70.0-67.0	66.0-62.0	55.0-50.0	43.0-37.0	34.0
Mileage from A.E.C. Intake	33-36	28-32	16-21	3-9	0
Audouinella	xx	xxx	xx	xx	-
Biddulphia	x	x	xxx	x	x
Cladophra	xxxxx	xxxxx	xxxxx	xxxxx	xxxx
Hydrodictyon	xxxxx	xx	xxxxx	-	-
Microspora	x	-	-	-	-
Oedogonium	xxx	xxxxx	xxxxx	x	-
Oscillatoria	x	x	xxx	x	-
Spirogyra	x	x	xx	-	-
Stigeoclonium	-	-	xxx	-	-
Tetraspora	-	-	xxxxx	-	-
Tribonema	-	x	x	x	-
Ulothrix	x	-	-	-	-

Key to symbols:

xxxxx = very abundant

x = rare

- = none reported

would probably break loose many of these growths and move them downstream. This might result in some difficulties in the A.E.C. water treatment system. Death and the resultant decay of these heavy growths could result in taste and odor conditions in the river water. In this respect, these algal growths represent potential nuisance conditions.

"Sewage fungus" was observed in the area below the Chillicothe sewer outfall and it formed an extensive blanket covering the river bottom in the area below Paint Creek. It is probable that the "sewage fungus" blanket will extend for a considerable distance downstream in winter. The first rise after a period of low flow in cold weather would bring much of this material downstream.

Phytoplankton

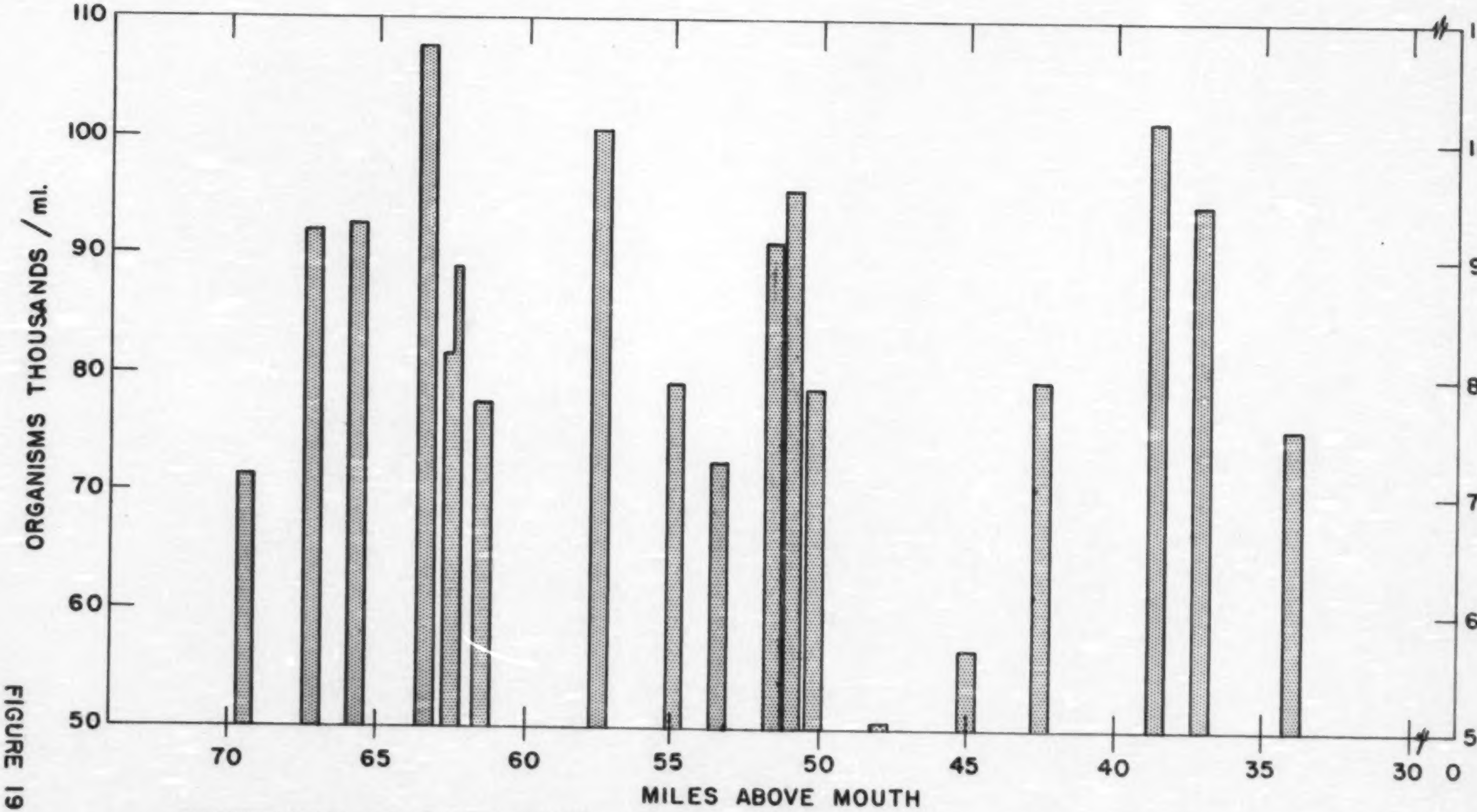
Analyses of the centrifuged plankton samples revealed that the phytoplankton was extremely abundant and varied. Many genera and species of algae were present but of these a few genera and generic groups comprised the bulk of the plankton.

The phytoplankton populations between Chillicothe and Piketon showed a fluctuation in numbers with peaks of extreme abundance at several stations (Figure 19). This stretch of river received the waste discharge from Chillicothe and Paint Creek, and the peak populations were probably caused by the fertilizing effect of this organic pollution. No such peak was found in the area of the A.E.C. water intake at the time these samples were taken, but such peaks in abundance usually vary in location with changes in stream conditions.

The most important group of algae in the plankton, from the standpoint of numbers, was that of the green algae (Chlorophyceae). There were more green algae at any given station than individuals of all the other algal groups combined. Two generic groups and a variety of other green algae, mostly members of the order Chlorococcales, combined to make the class Chlorophyceae the most abundant group both in kinds of algae and in numbers of individuals.

The most abundant of these generic groups of green algae was the Chlorella group. This group was composed of minute green unicells, most of which were Chlorella. Also present in this group were other small green unicells which could not be identified under the magnification at which the counts were made. However, under higher magnification (920 diameters) such organisms as spineless Ophiocytium and Lagerheimia, small resting stages of Chlamydomonas, and some small blue-green algae such as Chroococcus and fragmented Microcystis were noted. The second most numerous group of green algae was the Ankistrodesmus-Selenastrum group which consisted of several varieties of Ankistrodesmus falcatus, Selenastrum spp., and an occasional Kirchneriella. Scenedesmus bijuga and Scenedesmus spp. were also abundant.

The next most abundant groups of algae were the diatoms (Bacillarieae), represented mainly by Cyclotella and Nitzschia, and the pigmented flagellates, an artificial grouping consisting of flagellates belonging to several taxonomic groups. The most common forms in this latter group were Euglena group, consisting of Euglena. Phacus. Trachelomonas, Cryptoglena, and others; and the Chlamydomonas group, consisting of Chlamydomonas and related forms.



ABUNDANCE OF PHYTOPLANKTON IN SCIOTO RIVER — SEPTEMBER 23-25, 1953
SCIOTO RIVER STUDIES

FIGURE 19

The blue-green algae (Myxophyceae), as represented by Anabaena, the Oscillatoria group, and others, were the least abundant of the major groups. However, some of the cells in the Chlorella group may have been blue-green algae which could not be identified as such because of their small size.

Table 19 shows the distribution of phytoplankton in the series collected during September 23-25. The limited data obtained from collections of September 3, are not presented here. They indicated that the kinds of organisms present were essentially the same as in the later collections but there was an apparent increase in numbers from Chillicothe to the A.E.C. water intake.

Several types of nuisance algae were present in the plankton. The diatoms are frequent filter cloggers, the most frequent offender among them being Synedra. Synedra was found to be of widespread occurrence in the river, but never abundant. The only diatom which showed a steady downstream increase in the area studied was Cyclotella. This form is not often involved in nuisance conditions.

Several of the algae commonly associated with taste and odor production were found in the plankton. Hydrodictyon reticulatum and Fragilaria were present, but never in abundance. Both forms were normally components of the extensive marginal mats found along the river, and those individuals which were found in the plankton had undoubtedly broken loose from these mats. Ceratium carolinianum and Dinobryon were each found only once in the series analyzed. Other taste and odor algae present were Chlamydomonas, Oscillatoria, and Anabaena.

The last mentioned genus is one which has been implicated in numerous cases of poisoning of livestock and wildlife (30) (31) (32). It is also one of the most common algae in many polluted streams (33). Toxicity associated with Anabaena and related forms has been reported from lakes rather than from flowing streams, and only at times when the algae were present in such numbers as to cause a "surface bloom" (34) (35) (36). Anabaena was not abundant in the plankton and there was no evidence that it was producing toxic conditions in the Scioto River.

Extreme abundance of any one kind of alga may cause water treatment difficulties such as clogged filters or tastes and odors. Although algae commonly known as nuisance forms were not particularly abundant in the plankton, the abundance of other algae, particularly the great numbers of small unicellular algae in the Chlorella group, could possibly cause these problems in the operation of a water treatment system.

Oxygenation and the utilization of nutrients by the phytoplankton assist in purifying the stream. Photosynthetic activity of the abundant phytoplankton and filamentous algae is the most important factor in causing diurnal fluctuations in the dissolved oxygen (37). For example, during a twenty-four hour sampling period the dissolved oxygen at the A.E.C. intake structure varied from 5.5. ppm at 0600 hour to 11.7 ppm at 1600 hour. Another indication of algal activity may be seen from the chemical data as recorded in Table 5 which gives the summary of the 7-day sanitary examination. The data show a decrease in ammonia nitrogen (NH_3-N) between S-76.2 and the A.E.C. water intake at

TABLE 19
SCIOTO RIVER PHYTOPLANKTON
SEPTEMBER 23-25, 1953
ORGANISMS PER MILLILITER*

Date of Colletion	9/23/53					
River Miles	S-69.5	S-67.2	S-65.7	S-63.4	S-62.6	S-62.3
Time	0700	1015	1145	1315	1425	1515
BACILLARIEAE						
Synedra	200	100				
Nitzschia	400	600	700	600	1000	200
Cyclotella	1500	800	600	1500	400	400
Others	300	100	200	100		100
TOTAL	2400	1600	1500	2200	1400	700
CHLOROPHYCEAE						
Ankistrodesmus-Selenastrum group	9400	12000	13200	10800	9400	8400
Chlorella group	53100	70100	69300	89500	64100	73900
Scenedesmus bijuga	3300	4400	6200	2500	3000	2300
Scenedesmus spp.	300	200	200	400	500	700
Others	1900	2000	800	900	1600	1500
TOTAL	68000	88700	89700	104100	78600	86800
MYXOPHYCEAE						
Oscillatoria group	200	100	200			
Anabaena	100			300		200
Others		100	100			
TOTAL	300	200	300	300		200
PIGMENTED FLAGELLATES						
Euglena group	400	1200	800	400	1000	1000
Chlamydomonas group	100	300	600	700	300	400
Others	100				100	
TOTAL	600	1500	1400	1100	1400	1400
TOTAL PHYTOPLANKTON	71300	92000	92900	107700	81400	89100

* Taken at the surface in the channel except as otherwise indicated.

TABLE 19 (Cont'd-2)
SCIOTO RIVER PHYTOPLANKTON
SEPTEMBER 23-25, 1953
ORGANISMS PER MILLILITER*

Date of Collection	9/23/53			9/24/53		
River Miles	S-61.5	S-57.5	S-54.9	S-54.9	S-54.9**	S-53.4
Time	1600	1700	1745	0745	0800	0900
BACILLARIEAE						
Synedra	100		100			100
Nitzschia	200	1400	300	300	700	200
Cyclotella	1300	1000	700	1200	500	1300
Others						200
TOTAL	1600	2400	1100	1500	1200	1800
CHLOROPHYCEAE						
Ankistrodesmus-Selenaestrum	5800	10300	10600	8300	9900	8500
Chlorella group	65100	81800	57300	51100	56200	55100
Scenedesmus bijuga	2200	1900	2300	2600	2700	3500
Scenedesmus spp.	200	500	600	400	300	200
Others	1000	900	1100	1100	1600	1300
TOTAL	74300	95400	71900	63500	70700	68600
MYXOPHYCEAE						
Oscillatoria group	100	300	100	800	400	500
Anabaena	300	200	100	200		200
Others	200		100			
TOTAL	600	500	300	1000	400	700
PIGMENTED FLAGELLATES						
Euglena group	1000	1700	5300	1200	1100	1100
Chlamydomonas group	400	300	500	1100	600	300
Others				100	100	
TOTAL	1400	2000	5800	2400	1800	1400
TOTAL PHYTOPLANKTON	77900	100300	79100	68400	74100	72500

* Taken at the surface in the channel unless otherwise indicated

** Taken at 4-1/2' depth

TABLE 19 (Cont'd-3)
SCIOTO RIVER PHYTOPLANKTON
SEPTEMBER 23-25, 1953
ORGANISMS PER MILLILITER*

Date of Collection	9/24/53					
River Miles	S-51.6	S-51.6**	S-50.9***	S-50.9	S-50.9	S-50.2
Time	1000	1000	1100	1100	1200	1300
BACILLARIEAE						
Synedra	100	100	200			200
Nitzschia	200	200	1200	400		300
Cyclotella	1100	800	2600	1400	1500	2000
Others	200		1200	200	100	200
TOTAL	1600	1100	5200	2000	1600	2700
CHLOROPHYCEAE						
Ankistrodesmus-Selenastrum group	9100	9800	7000	10100	8200	9400
Chlorella group	71800	58000	50200	73500	62900	57100
Scenedesmus bijuga	3000	2700	2200	8000	3900	4700
Scenedesmus spp.	400	400	500	500	600	200
Others	1400	1000	2000	1200	1200	2100
TOTAL	85700	71900	61900	88300	76800	73500
MYXOPHYCEAE						
Oscillatoria group	100	200	400	200	400	200
Anabaena	200	200	600	600	200	500
Others			100		600	
TOTAL	300	400	1100	800	1200	700
PIGMENTED FLAGELLATES						
Euglena group	2400	2000	2100	3000	1600	1500
Chlamydomonas group	1100	500	500	1200	400	500
Others		100	100		100	
TOTAL	3500	2600	2700	4300	2100	2000
TOTAL PHYTOPLANKTON	91100	76000	70900	95400	81700	78900

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* Taken at the surface in the channel unless otherwise indicated

** Taken at 6' depth

*** Taken near the shore

TABLE 19 (Cont'd-4)
SCIOTO RIVER PHYTOPLANKTON
SEPTEMBER 23-25, 1953
ORGANISMS PER MILLILITER*

Date of Collection	9/24/53					9/25/53
River Miles	S-48.0	S-45.0	S-42.5	S-38.6	S-37.1	S-34.0
Time	1400	1500	1600	1700	1800	0930
BACILLARIEAE						
Synedra			100		200	100
Nitzschia		200	300	200	100	600
Cyclotella	1400	2200	4600	7200	7800	8500
Others		200	200	200	600	100
TOTAL	1400	2600	5200	7600	8700	9300
CHLOROPHYCEAE						
Ankistrodesmus-*Selenastrum* group	6300	7000	7200	9600	9600	8800
Chlorella group	36200	38600	56300	71800	64200	44000
Scenedesmus bijuga	1000	1900	2100	2400	1100	2000
Scenedesmus spp.	500	800	1000	1500	1300	2200
Others	1800	800	2200	2700	4900	4600
TOTAL	45800	49100	68800	88000	81100	61600
MYXOPHYCEAE						
Oscillatoria group	100	100	600	300		
Anabaena	400	400	300	1000	1000	1100
Others	100	500	200	200	100	800
TOTAL	600	1000	1100	1500	1100	1900
PIGMENTED FLAGELLATES						
Euglena group	2100	2700	3300	4000	3400	2300
Chlamydomonas group	700	1400	700	500	400	400
Others		200	400		100	300
TOTAL	2800	4300	4400	4500	3900	3000
TOTAL PHYTOPLANKTON	50600	57000	79500	101600	94800	75800

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* Taken at the surface in the channel unless otherwise indicated

S-34.0 without an accompanying increase in nitrate nitrogen (NO_3-N), indicating that the converted nitrates are being utilized by the algae.

Zooplankton

The two series of net plankton samples taken during September were analyzed with the object of determining the zooplankton population densities in the river. The results of these analyses are presented in Tables 20 and 21.

The zooplankton of the river was abundant (Tables 20 and 21), and consisted mostly of rotifers and protozoans. Crustacea were present but never generally abundant. Concentrations of Cladocera were observed in the marginal algal mats at S-54.9 on September 3. A sample collected from the river at this point on September 23 revealed a crustacean population of 68 per liter. Of these, 40 per liter were the cladoceran, Moina. This was the only sample in which a significant number of microcrustacea was found.

Insects were found occasionally in the plankton but they are not true planktonic (free-floating) forms. The only significant number of insects at any one station was found in a sample from S-50.9 in which 52 insects per liter, mostly Corixidae, were found. These insects were observed in great abundance in shallow areas at several places along the river. Since this sample was taken near shore, it is obviously unrepresentative of the river as a whole at that point.

Rotifers comprised the majority of the zooplankton. Brachionus was the most abundant form in the upstream stations, but other genera became predominant below S-63.4. The heaviest rotifer populations were found in the area at and below Higby Bridge, S-54.9. A net plankton sample taken from this station at 0745 hour, September 24, revealed that most of the rotifers there were dead or dying. At that time the dissolved oxygen was 0.1 ppm and this rotifer mortality may be attributed to pollution. Other samples from this area showed high populations of living rotifers, but they were taken at 1800 hour when the dissolved oxygen was higher because of algal photosynthesis. Chemical data taken from September 23 to September 29 showed that the dissolved oxygen at Higby Bridge was 0.0 ppm between 0550 hour and 0750 hour.

Protozoa comprised the second most numerous group of zooplankton organisms in the river. Pigmented flagellates of several kinds were abundant, and these are dealt with under the heading of phytoplankton. Various kinds of ciliates were the most abundant unpigmented protozoans. Some of these, such as Vorticella and Epistylis, were probably capable of living unattached after having been separated from the substrates to which they were originally attached.

In general, the data show a decreased zooplankton population in the stations closest to Piketon. In both series of samples analyzed, the lowest zooplankton densities were found at the A.E.C. water intake at Piketon. However, as is the case with the phytoplankton, the areas of greatest abundance changed with physical and chemical changes in stream conditions. Further variations were undoubtedly caused by diurnal migration. Rotifers, and other organisms commonly migrate vertically from one to three meters or more daily. Microcrustaceae migrate even greater distances daily, and they often occur in "swarms," or limited areas of great abundance. An extensive series of samples would be

TABLE 20
SCIOTO RIVER ZOOPLANKTON
SEPTEMBER 23-25, 1953
ORGANISMS PER LITER*

Date of Collection	9/23/53					
River Miles	S-69.5	S-67.2	S-63.4	S-62.6	S-57.5	S-54.9
Time	0800	1015	1315	1430	1700	1800
PROTOZOA						
Amoeba	8	3	3		13	5
Difflugia	10	3	35	13		18
Ciliata	18	13	28	43	38	108
Holotricha	3		5		3	70
Vorticella		3	3			30
Others	3	3	21	10	5	6
TOTAL	42	25	95	66	59	237
ROTIFERA						
Asplanchna	25	38	10		3	5
Brachionus	600	625	58	45	28	210
Keratella	13	20	13	5	5	
Rotaria			3		18	15
Rotifer eggs	15	13	23	3	30	38
Others	37	18	23	54	171	633
TOTAL	690	714	130	107	255	901
NEMATODA					3	
TOTAL					3	
OLIGOCHAETA						
Naididae						
TOTAL						
CRUSTACEA						
Daphnia						
Moina						40
Cyclops	3				3	15
Nauplius	3	10	3	10	8	13
TOTAL	6	10	3	10	11	68
INSECTA						
Corixidae						
Chironomidae						8
Ceratopogonidae						
TOTAL						8
TOTAL ZOOPLANKTON	738	749	228	183	328	1214

* Taken at the surface in the channel except as otherwise indicated

TABLE 20 (Cont'd-2)
SCIOTO RIVER ZOOPLANKTON
SEPTEMBER 23-25, 1953
ORGANISMS PER LITER*

Date of Collection	9/24/53						
River Miles	S-54.9	S-53.4	S-51.6	S-50.9**	S-50.9	S-50.9	S-50.2
Time	0745	0900	1000	1100	1100	1200	1300
PROTOZOA							
Amoeba	5	8		5	35	5	10
Difflugia	3	18	5	25	3	5	20
Ciliata	38	130	143	45	116	70	113
Holotricha		103		10	70	5	20
Vorticella		68	35	5	28	10	10
Others	8	10	11	10	13	5	18
TOTAL	54	337	194	100	265	100	191
ROTIFERA							
Asplanchna		3	3				2
Brachionus	30	20	70	15	35	28	40
Keratella	3		3		3		3
Rotaria	65	58	15	5		3	8
Rotifer eggs	58	33	15	25	8	8	18
Others	256	1655	273	150	173	121	66
TOTAL	412	1769	379	195	219	160	137
NEMATODA		3		15			
TOTAL		3		15			
OLIGOCHAETA							
Naididae		5					
TOTAL		5					
CRUSTACEA							
Daphnia							
Moina							
Cyclops							
Nauplius							
TOTAL							
INSECTA							
Corixidae				37			
Chironomidae				10			
Ceratopogonidae				5			
TOTAL				52			
TOTAL ZOOPLANKTON	466	2114	573	362	484	260	328

* Taken at the surface in the channel except as otherwise indicated
** Taken near the shore

TABLE 20 (Cont'd-3)
SCIOTO RIVER ZOOPLANKTON
SEPTEMBER 23-25, 1953
ORGANISMS PER LITER*

Date of Collection	9/24/53					9/25/53
River Miles	S-48.0	S-45.0	S-42.5	S-38.6	S-37.1	S-34.0
Time	1400	1500	1600	1700	1800	0930
PROTOZOA						
Amoeba						
Difflugia	10	28	15	15	13	5
Cilliata	16	28	8	18	18	10
Holotricha		10			8	5
Vorticella	15	13	3	5	13	3
Others	3	5	5	3	3	3
TOTAL	44	84	31	41	55	26
ROTIFERA						
Asplanchna	23	5		3	3	
Brachionus	30	73	13	45	200	5
Keratella		5	3			
Rotaria						
Rotifer eggs	15	18	23	15	43	13
Others	38	28	15	33	49	28
TOTAL	106	129	54	96	295	46
NEMATODA						
TOTAL						
OLIGOCHAETA						
Naididae						
TOTAL						
CRUSTACEA						
Daphnia						3
Moina						
Cyclops	3					
Nauplius			3	3		
TOTAL	3		3	3		3
INSECTA						
Corixidae						
Chironomidae			3			
Certatopogonidae						
TOTAL			3			
TOTAL ZOOPLANKTON	153	213	91	140	350	75

* Taken at the surface in the channel except as otherwise indicated

TABLE 21
SCIOTO RIVER ZOOPLANKTON
SEPTEMBER 3, 1953
ORGANISMS PER LITER*

River Miles	S-63.4	S-54.9	S-45.0	S-34.9
Time of Collection	0745	0900	1015	1230
PROTOZOA				
Amoeba		10		
Difflugia				15
Ciliata	3	45	3	5
Vorticella		120		5
Others			3	
TOTAL	3	175	6	25
ROTIFERA				
Asplanchna		38		
Brachionus	98	33	10	3
Rotaria		8		
Rotifer eggs	38	10	3	
Others	53	231	29	11
TOTAL	189	320	42	14
OLIGOCHAETA				
Naididae		5		
TOTAL		5		
CRUSTACEA				
Cladacera		3		
Nauplius	5			
TOTAL	5	3		
TOTAL ZOOPLANKTON	197	503	48	39

* Taken at the surface

necessary to estimate accurately their abundance in the river. An examination of the data taken from S-54.9 and S-50.9 (Table 20) will show that there is a wide variation in the numbers of zooplankton from the same sations at different times.

The abundant zooplankton population is indicative of stream conditions in the Scioto River. It is a reflection of the high biological productivity of the river, and of the heavy phytoplankton and bacterial populations upon which it feeds. The zooplankton are unlikely to influence the operation of the A.E.C. water treatment system. When biologically caused operational problems occur in such systems, they are usually attributable to algae. While zooplanktonic organisms, such as those which are common in the Scioto River, may be present in association with these algae, they are usually not the organisms causing taste and odor or other difficulties.

Summary

Examination of the plankton, attached algae, and floating mats collected during September showed the Scioto River to be highly productive of these forms. The phytoplankton and zooplankton populations were abundant, and there were extensive bottom growths and many areas with floating mats of algae. "Sewage fungus" was observed in the area below the Chillicothe sewer outfall, and it blanketed the river bottom in the area below Paint Creek. These extensive growths of the larger algae and "sewage fungus" represent potential nuisances. During September the algae were less abundant in the immediate area of the A.E.C. intake than farther upstream, but an increased water level would probably carry much of this material downstream. This could result in water treatment problems at the A.E.C. plant. Death and decay of these masses of algae and "sewage fungus" could also cause taste and odor in the raw water.

There were considerable fluctuations in the total numbers of the phytoplankton and zooplankton populations at the stations between Chillicothe and Piketon. The locations of the peaks of abundance of both types of organisms were determined by such stream conditions as rate of flow, temperature, and other factors which influence the rate at which nutrients become available to the algae. These peaks of abundance will probably vary in magnitude and location as stream conditions vary.

The phytoplankton represented possible nuisance conditions because of its abundance. None of the algae commonly associated with severe taste and odor or filter clogging problems were numerous in the plankton during September 1953, but the extreme abundance of any algal form could result in nuisances.

The abundant populations of organisms found in the Scioto River play an important role in the natural purification of the stream through such activities as the release of oxygen during photosynthesis, predation, and utilization of nutrients.

REFERENCES CITED

(1) *Manual of Recommended Water Sanitation Practice.* Public Health Bulletin No. 296. U. S. Public Health Service, Washington, (1946).

(2) "Public Health Service Drinking Water Standards." *Public Health Rep.*, *61*, 371-84. (1946). Reprint No. 2697.

(3) Kehr, Robert, W., Purdy, W. C., Lackey, James B., Placak, Oliver R., and Burns, William B., *A Study of the Pollution and Natural Purification of the Scioto River.* Public Health Bulletin No. 276. U. S. Public Health Service, Washington (1941).

(4) Smith, Robert C., and Schmidt, James J., *The Water Resources of Pike County, Ohio.* Information Circular No. 1. Ohio Department of National Resources, Division of Water, Columbus, Ohio (1953).

(5) *Summary Report on Water Pollution, Ohio River Drainage Basin.* Public Health Service Publication No. 136. U. S. Public Health Service, Washington (1951).

(6) *Ohio Valley Flood Control Plan.* Corps of Engineers, U. S. Army, Ohio River Division, Cincinnati, Ohio (February, 1941).

(7) "Scioto River Basin," *Ohio River Pollution Control*, Part 2, Report of the U. S. Public Health Service. House Document No. 266, 78th Congress, 1st Session, Washington (1944).

(8) Cross, William P., and Bernhagen, Ralph J., Ohio Stream-Flow Characteristics, Part 1, Flow Duration, Bulletin 10. Ohio Department of Natural Resources, Division of Water, Columbus, Ohio (September, 1949).

(9) Cross, William P., and Webber, Earl E., Ohio Stream-Flow Characteristics, Part 2, Water Supply and Storage Requirements, Bulletin 13. Ohio Department of Natural Resources, Division of Water, Columbus, Ohio (December, 1950).

(10) Census of Water and Sewage Works, U. S. Public Health Service, Washington (1949).

(11) Lamar, William L., and Schroeder, Merle E., Chemical Character of Surface Waters in Ohio, 1946-1950, Bulletin 23. Ohio Department of Natural Resources, Division of Water, Columbus, Ohio (June, 1951).

(12) Standard Methods for the Examination of Water and Sewage, 9th Ed. American Public Health Association, New York, p. 193 (1946).

(13) Maxcy, K. F., Rosenau—Preventive Medicine and Hygiene, 7th Ed. Appleton-Century-Crofts, Inc., New York (1951).

(14) Walton, Graham, "Survey of the Literature Relating to Infant Methemoglobinemia Due to Nitrate Contaminated Waters." American Journal of Public Health. 41, 986 (August, 1951).

(15) Waring, F. H., "Significance of Nitrates in Water Supplies." Jour. Am. Water Works Assoc., 41, 147 (1949).

(16) Megregian, S., and Solet, Ira, "Critical Factors in Fluoride Distillation Technique." Journal American Water Works Association, 45, 1110 (1953).

(17) Megregian, S., and Maier, F. J., "Modified Zirconium-Alizarin Reagent for Determination of Fluorides in Water." Journal American Water Works Association, 44, 239 (1952).

(18) Okun, D. A., "Public Health Importance of Water Supply and Waste Disposal Works," Separate No. 252. Proc. American Society of Civil Engineers, Vol. 79 (August, 1953).

(19) Degens, P. N., Jr., Van der Zee, H., and Kommer, J. D., "Routine Method for Determination of Sulfate and Sulfonate Anion - Active Synthetic Detergents in Sewage." Sew. and Ind. Wastes, 25, 24 (1953).

(20) Environmental Health Center, U. S. Public Health Service. Unpublished data.

(21) Ohio Department of Health. Unpublished data.

(22) Sisley, J. and Wood, P. J., Encyclopedia of Surface Active Agents. Chemical Publishing Co., New York (1952).

(23) Fleet, L. and Hoyt, L. F., "Detergent Compounds - Their Composition and Behavior." Sew. and Ind. Wastes, 25, 245 (1953).

(24) "Effect of Detergents on Sewage and Water Treatment." Chem. Eng. News, 31, 1072 (1953).

(25) "Correction of Tastes and Odors Resulting from Detergents." Taste & Odor Control Journal. 19, 6 (June, 1953).

(26) Keenan, R. G., and White, C.E., "Supression of Cyanogen Bands in the Direct Current Graphite Arc by Lithium Chloride." Anal. Chem., 25, 889 (1953).

(27) Water Quality and Treatment, The American Water Works Association, Inc., New York (1950).

(28) Braus, H., Middleton, F. M., and Walton, G., "Organic Chemical Compounds in Raw and Filtered Surface Waters." Anal. Chem., 23, 1160 (1951).

(29) Middleton, F. M., Braus, H., and Ruchhoft, C. C., "Fundamental Studies of Taste and Odor in Water." Journ. of Am. Water Works Assn., 44, 538 (1952).

(30) Wheeler, R. E., Lackey, James B., and Schott, Stuart, "A Contribution on the Toxicity of Algae." Public Health Reports, 57, 1695-1701, (November 6, 1942).

(31) Ingram, William Marcus, and Prescott, George W., Illustrations of Fresh-water Algae Toxic to Animals. Ohio-Tenn. Drainage Basins Office, U. S. Public Health Service, Cincinnati, Ohio, (June, 1952).

(32) Pammel, H. H., "Poisonous Blue-green Algae." Veter. Medic., 20, 23, (1925).

(33) "Biological Studies," Ohio River Pollution Control, Part 2, Report of the U. S. Public Health Service. House Document No. 266, 78th Congress, 1st Session, Washington (1944).

(34) Fitch, C. P. et al., "'Water Bloom' As a Cause of Poisoning in Domestic Animals." Cornell Vet., 24, 31-40 (Jan., 1934).

(35) Prescott, G. W., "Objectionable Algae with Reference to the Killing of Fish and Other Animals." Hydrobiologia, I, 1-13 (August 15, 1948).

(36) Stewart, A. G., Barnum, D. A., and Henderson, J. A., "Algal Poisoning in Ontario." Canad. Jour. of Comparative Med., 14, 197-902 (June,1950).

(37) Tarzwell, Clarence N., and Gaufin, Arden R., "Some Important Biological Effects of Pollution Often Disregarded in Stream Surveys." Proc. 8th Industrial Waste Conf., Purdue University Eng. Bull. (May, 1953).